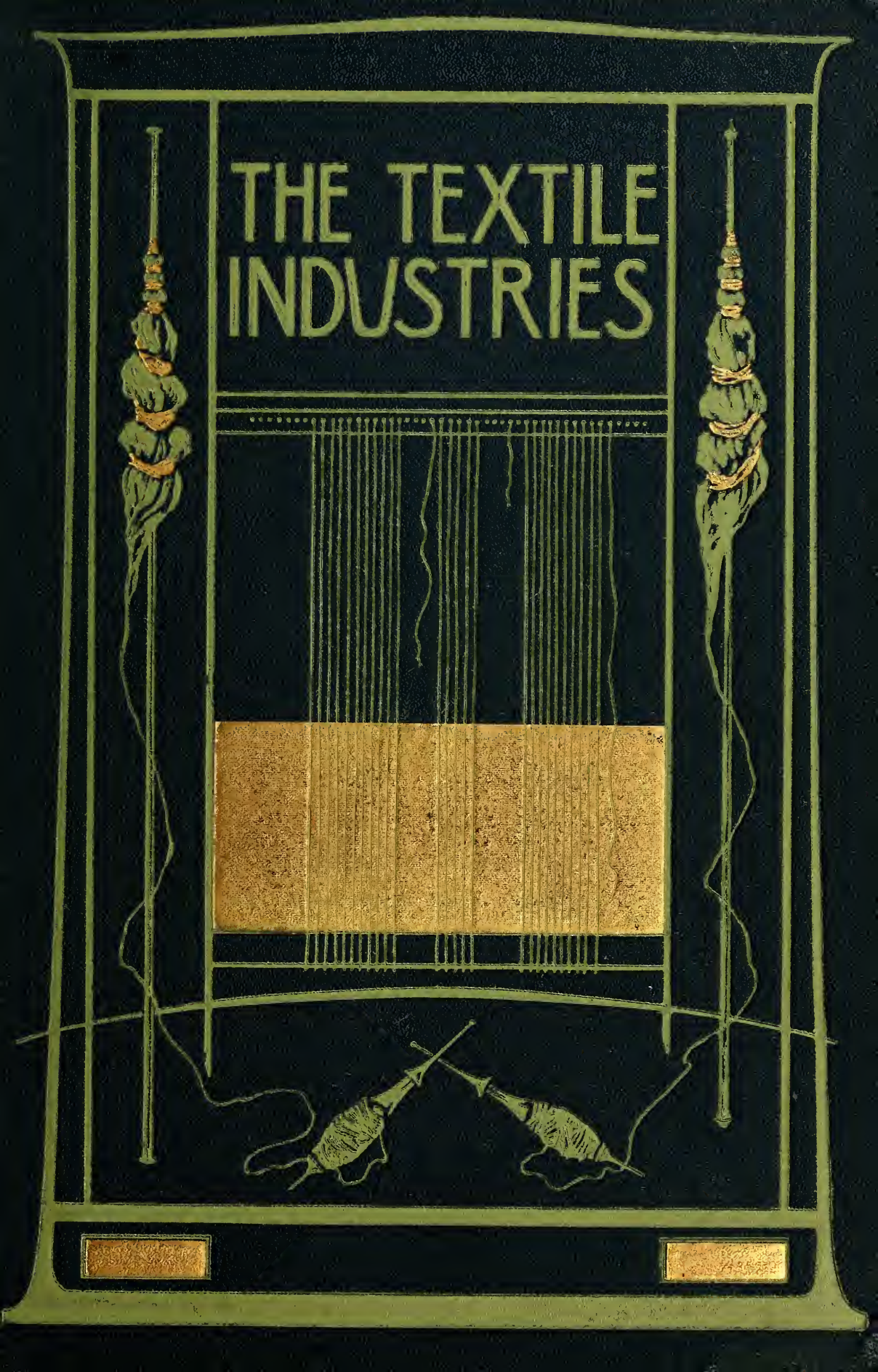
THE TEXTILE INDUSTRIES



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THE TEXTILE INDUSTRIES

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A TAPESTRY DESIGN

(By Edmund Hunter, St. Edmundsbury Weaving Works, Letchworth)

(By Edmund Hunter, St. Edmundsbury Weaving Works, Letchworth)

THE TEXTILE INDUSTRIES

A PRACTICAL GUIDE to FIBRES YARNS & FABRICS in every branch of Textile Manufacture

including Preparation of Fibres
Spinning Doubling Designing
Weaving Bleaching Printing
Dyeing and Finishing

BY WILLIAM S. MURPHY

Assisted by Leading Experts
in Textile Technology

VOLUME II

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The Preparation of Textile Fibres

CHAPTER III

The Preparation of Flax and Hemp

Flax and its Uses.—Flax is the most serviceable of the long vegetable fibres. During the past two centuries its importance in the textile world has gradually declined, and many think it likely to decline still further. Cotton and waste silk now serve many purposes formerly fulfilled by flax, and ramie, according to some, threatens to lower its importance to a minimum.

In Belgium, Holland, France, and Austria the fibre is highly cultivated, and made into thread for the fine laces fabricated in those countries. No fibre yet discovered possesses the peculiar combination of qualities which render flax the material most suitable for lace fabrics.

Up till the middle of the nineteenth century flax thread, or lint, was the staple sewing material of this country; but the advent of the sewing machine gave the cotton-thread manufacturers an opportunity they were not slow to grasp. A lighter, softer, more flexible, and cheaper thread was required for the sewing machines, and cotton supplied the need. Thus brought into prominence, cotton entered more and more into use as a sewing material, especially for light garments and ladies' dresses. For a time, indeed, it seemed as if the lighter fibre was going to sweep flax out of the thread market; but reaction set in, and the provinces of the two kinds of threads became clearly defined, lint being accepted as the material for stout service and for certain kinds of fancy and coloured work, while cotton kept hold of the machines and lighter uses.

For shoemakers, saddlers, leather-bag makers, and all leather workers, lint is the staple thread. Upholstery, bookbinding, and trades requiring threads lasting and strong, and proof against damp or changes in temperature, employ flax. Before cotton could be spun into threads strong enough for cloth warps, linen was the warp material. At present it is the warp and weft of carpets of all kinds, binding the pile warp, though cotton and jute are also used. For upholstery plushes and various ornamental fabrics lint is the main resort. However, the bulk of the flax grown on the fields of the world goes to make linen cloths. The principal classes of these are sheetings, towellings, lawns, damasks, diapers, long-cloths, and cambrics.

Linen.—So far as can be ascertained, linen seems to have been the first form of woven cloth. We certainly know that the cloths which have been longest in existence are of that material. In the antique civilized world the wearing of fine linen was regarded as a sign of wealth and refinement. Easily bleached to a glistering whiteness, the cloth was much valued as a ceremonial dress material among the high dignitaries of the ancient empires of the south. The records of Egypt, Persia, Babylon, Phœnicia, Greece, and Rome contain many references to "fine linen", which the gorgeous imagination of the East combined with purple. But linen was also the clothing of the common people, and northern nations, even in prehistoric times, knew something of the cloth. It may be safely said that, shortly before the Christian era, the majority of the civilized nations wore more linen than any other cloth. As we have already hinted, however, linen was gradually displaced by woollen fabrics, and then cotton came to contest supremacy with wool in the textile world, and partly supersede the harder, stronger fabric we call linen in nearly every province.

On the face of it, the victory of cotton over flax is almost inexplicable. Linen is the more durable, hygienic, beautiful, and pleasant fabric; it bleaches to a purer white and takes on a glossier finish. Cotton, however, is more easily manipulated than linen, and, above all, it is cheaper.

British Linen Manufacture.—Though one of the smaller branches of the textile industry, linen manufacture is carried on in places widely separated from each other. It is as if a net spread over the land had been cut and gathered into knots at certain places. Historical fact bears out the suggestion. Linen manufacture was practised as a domestic industry in every locality. Flax was grown, spun, and

woven into cloth in every parish; but farmers saw it to be their interest to grow corn, breed sheep, horses, or cattle, and purchase woollens and cottons from the great manufacturers in the centres of those industries. Linens, too, they bought in the towns. One by one the little knots of weavers were broken, and either starved or migrated to where their weaving abilities might find a market. The far-spread trade was gathered into a few centres—Leeds and round Manchester, in England; Dundee and Dunfermline, in Scotland; Limerick, Belfast, and a few towns of the province of Ulster, in Ireland.

The history of linen manufacture is curiously complicated by ill-advised attempts to arrest the stream of economic tendency. We offer no opinion on the general question of government assistance to industries. Wise furtherance of an industry here or there may come to be an important function of government, but the interferences of the British Government with the linen industry were unwise from first to last, and in almost all particulars.

During the reigns of Charles II, William III, and Queen Anne successive enactments were made by Parliament prohibiting the export of woollen goods from Ireland, while, on the other hand, Irish linen manufacture was fostered and encouraged. The woollen industry of Ireland was killed, and the linen industry grew under artificial stimulus far beyond its natural dimensions. In 1711 a Board named "The Trustees for the Linen Manufacture" was established by Act of Parliament, the business of which was to stimulate the linen trade of Ulster by the distribution of grants, which, commencing at £6000 per annum, soon increased to £20,000. This system was continued up till 1828, when it was abolished, the abuses and futility of bounties and grants having become very apparent to everyone. The industry languished, and frightful sufferings among the peasants and artisans ensued. To remedy this state of matters the Royal Flax Improvement Society was formed under royal patronage, but it also died a natural death about eighteen years later. In 1852 a committee was formed under sanction of the Belfast Chamber of Commerce to issue a weekly circular for the trade. Sixteen years later the Belfast Flax Supply Association was constituted. Originating from the industry itself, these organs have performed useful work. At the present time the whole linen industry of Ireland shows signs of renewed vigour, owing to the free and healthy energy of the manufacturers themselves.

Of the linen industry in Scotland a similar story of futile stimulus has to be told. The Board of Manufactures set up in Scotland, in 1727, for the distribution of bounties, pursuant to the Act of Union, distributed £2650 of its £6000 of annual income in fostering the linen industry, giving premiums for flax-growing, establishing schools of instruction in the arts of spinning and weaving, and subsidizing new factories. It was all of no avail; flax went out of cultivation; the cotton factory took the place of the spinning wheel; the rural weaver was driven into the city. Very significant is the fact that, in 1727, the year when the bounty system commenced, the weavers of Lanarkshire wove 272,000 yd. of linen; in 1822, the year before the system was abolished, the product of that county had declined to 22,869 yd. Economic causes, historical accidents, and mechanical developments combined to concentrate the linen industry in Dundee, Dunfermline, and some of the smaller towns on the east coast, where it still remains.

The linen industry fared badly in England. Because only the pursuit of small farmers and isolated weavers, and therefore unaided by any influential section of society, it was handicapped by the preferences given to Ireland and Scotland, crushed in the rural districts, and only saved from extinction by the enterprising energy of a few manufacturers in Lancashire and Yorkshire. Despite manifest disadvantages, the linen industry of England stands second only to that of Ireland.

Process of Linen Manufacture.—Flax is a long fibre, and it is prepared on the fields, and in the scutching mills attached, for textile uses. Here are no short and tangled fibres such as we find in wool and cotton; but the flax manufacturer has problems and difficulties of his own to solve. The fine fibres of the flax are irregularly connected by the dried vegetable gum of the plant; they hold together by various ties, and must be completely separated. Dirt also and short fibres are to be got rid of before the flax can become a textile thread. We have said that the true raw material of the spinner is the sliver, and the business of the fibre preparer is to bring the material into the form of that thick, soft rope. The stages of the process may be defined as follows:—

1. *Cutting.*—The finest long flax is cut into three parts, the top, the middle, and the root end, for close grading.

2. *Roughing.*—By a kind of rough hackling, the long are cleaned and separated from the shorter fibres.

3. *Hand Hackling.*—Some classes of flax are wholly prepared by hand. In this case the fibres are drawn through a succession of combs, each one finer than the one preceding.

4. *Machine Hackling.*—By means of machines the fibres are finely separated and combed out.

5. *Dressing and Sorting.* — When the fibres come off the first hackling machine they are of many sorts and sizes. To obtain the material from which a uniform yarn can be made, we require to sort out the various fibres into classes.

6. *Spreading.*—This is our last preparatory process, and corresponds to carding in the cotton factory. The spreading frame is equipped with needles which draw out and part the fibres, and in the end form them into a sliver.

7. *Tow Carding.*—The short fibres rejected in the above process are called *tow.* By a carding operation these fibres are smoothly combined into a sliver which passes into the hands of the spinners for conversion into yarn.

Classes of Flax.—The wide range of varieties of flax, and the various countries in which it is grown, render the classification of the fibre rather complex. At Riga, the port from which British manufacturers derive large supplies, the ordinary brands are: K, crown; P K, picked crown; H P K, light picked crown; S P K, superior picked crown; I S P K, light superior picked crown. The Livonian brands are: H D, hoffs dreiband; W H D, white hoffs dreiband; P H D, picked hoffs dreiband; W P H D, white picked hoffs dreiband; F P H D, fine picked hoffs dreiband; W F P H D, white fine picked hoffs dreiband; S F P H D, superior fine picked hoffs dreiband; W S F P H D, white superior fine picked hoffs dreiband. By a similar method the lower qualities of Riga flaxes are classed: W, wrack; P W, picked wrack; W P W, white picked wrack; G P W, grey picked wrack; D, dreiband; L D, Livonian dreiband; S D, Slanitz dreiband; P D, picked dreiband; P L D, picked Livonian dreiband; P S D, picked Slanitz dreiband.

From Archangel we derive quantities of flax, which are classed as: 1st, 2nd, 3rd, and 4th crown; 1st and 2nd Zabrack. Good qualities of flax are imported from Germany, chiefly through Königsberg, the brands of which are also closely graded. Higher kinds are drawn from Holland, Belgium, and France, the methods of grading being similar. Home-grown flax is classed according to the fineness and length of the fibre. Details of these latter classes are

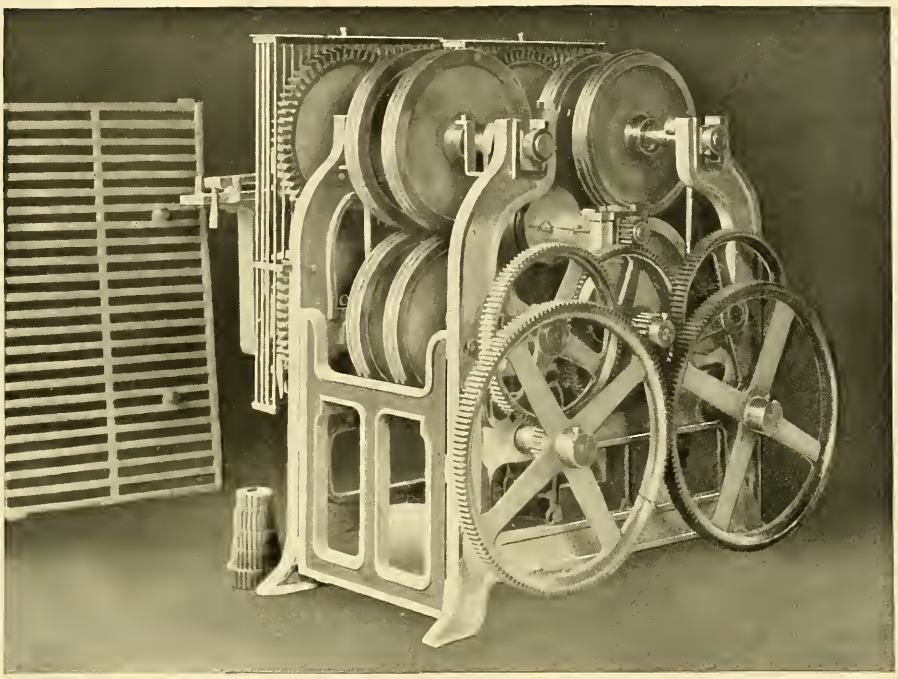
given every week in the *Linen Trade Circular* and the various trade journals.

When the scutched flax arrives at the factory it is made up in parcels divided into sections weighing 1 stone each, in which there are 112 pieces, or handfuls, which again are divisible into fingers, two to each piece. The weights vary, and the number of fingers in the bundle varies in consequence; but the worker is left in no doubt regarding the kind, quality, and weight of the fibres he is handling, because the weight and class in every parcel are systematically marked on each.

Cutting.—Being a bast fibre, and grown round a stalk tapering from root to top, flax naturally fines towards the head, the fibres near the root being thicker and coarser. In common kinds this feature is not very pronounced, nor does it matter seriously; but in the longest and finest flaxes, employed for the highest textile purposes, the difference is considerable and of importance. To obtain uniform qualities of fine fibre the long flax is cut into three — the *top*, the *middle*, and the *root end*.

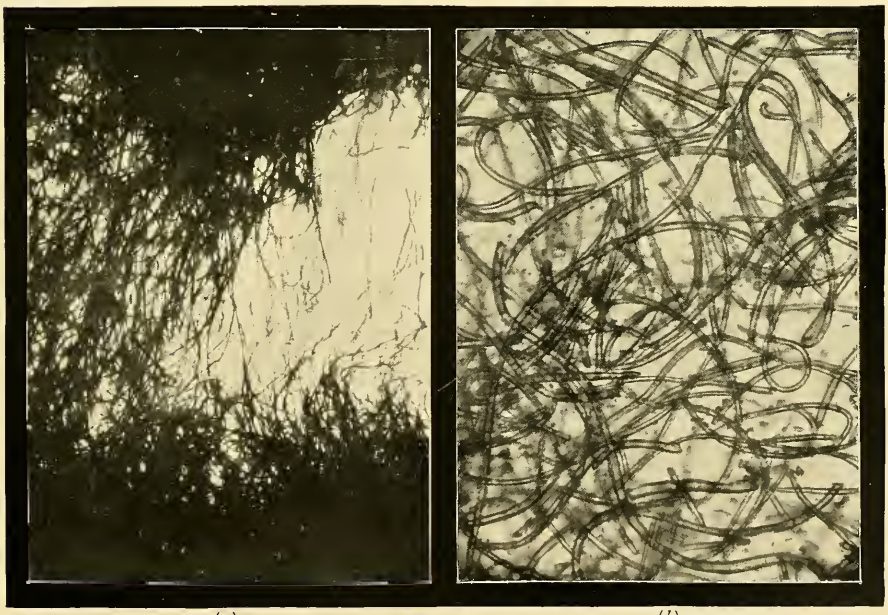
The cutting machine is a circular saw of special structure. Three plates of steel, with toothed edges, are firmly bolted together to form the saw. About 20 in. in diameter, the saw is hung on a spindle, on the end of which are the driving and loose pulleys of the driving belt. In front of the saw a pair of grooved pulleys sit at right angles on each side, with guards or holders over them. Fed into the grooves of the pulleys, the flax comes in front of the saw running at a high speed. Generally the root end is fed in first, and the regulator is set so as to cut through the fibres at the point desired—say a fourth of the whole length. All the root ends cut off, the flax is again fed through the machine, the part remaining being halved. Three classes of flax are thus obtained—the coarse and strong root ends, the fine and strong middle, and the finest, but not so strong tops. These are collected into separate heaps, and divided into *stricks*. Wefts of the finest cambrics can be spun from the tops.

Roughing.—From a spinner's point of view raw flax is defective in several particulars. The fibres are dirty and lie unevenly, and the long are mixed with the short; more important still, the fibres are gummed in irregular masses. The work of the rougher, or rough hackler, is the first to attempt remedy of these defects. If he gets all the root ends to lie even, the larger masses to separate, and the dirt and short fibres out of the way, he will have done very well. The



FLAX-CUTTING MACHINE: Gearing Covers removed

(Combe, Barbour, & Combe, Ltd., Belfast)



(*a*) (*b*)

(*a*) TORN FELT FIBRES; AND (*b*) PORTION OF SAME, MAGNIFIED

(See page 112)

finer accomplishments are achieved by other instruments and operations.

The tool of the rougher is a steel comb fixed in a tin-covered stock, scarcely 1 in. thick. The teeth are 7 in. long, ¼ in. square at the base, and tapered to a fine point. Screwed on to a board all ways larger than itself, the stock is fixed to the roughing bench slantwise, the teeth inclined to the back. To prevent the flax from entering too deeply into the comb, a slanting board is placed behind it.

Before commencing to hackle with the comb, the rougher performs an operation which greatly facilitates his work. This is called *piecing out.* Opening out the stone of flax, he finds it in eight or more stricks, which are again divided into two *fingers.* Laying the flax down in a convenient position, he selects as much as can be held between the forefinger and thumb, and draws it swiftly away. Giving the selected bunch of flax a swing round, he lays it flat on the bench, the swinging movement imparting to it a semicircular shape. In the same manner another bunch is selected and laid a little to one side of the first, the root end projecting so that it may be easily grasped without disturbing the one beside it. Thus, in long rows, the fibres are pieced out till the rougher has as much as keeps him working for an hour or two.

The rougher is now ready to begin. Grasping a piece near the top end, he gives it a back jerk, throwing it behind him with a lashing movement, causing the fibres to spread out, and then brings the whole bunch on the teeth of the hackle. Pulling by the top end, he leaves a portion of the short fibres in the hackle, with the root ends even. Next, the rougher takes the root ends between finger and thumb, and placing the piece over the corner pins of the hackle, pulls away any fibres that will come, leaving another portion in the comb. Grasping the remaining fibres by the middle, the worker thrusts them down into the hackle, and draws the whole piece through, with the root ends square. Winding the top end round his hand to prevent the flax from slipping, he proceeds by a circular sweep of his hand to lash the root end of the fibres in the teeth of the hackle, commencing as near the extremity as possible, and gradually working up to his grasp, collecting the fibres every now and again by holding his left hand in front of the *ruffer*, and turning the flax from time to time. When the root end has been sufficiently roughed, the operative takes hold of the piece by the part which has been wrought,

and proceeds to rough the top ends in a similar manner. Standing upright on the bench is a sharp-cornered pin of iron, named the touch pin. When well roughed, the fibres are caught by the root ends with the left hand and passed round the touch pin, while with his right hand the rougher jerks off the straggling and loose fibres. Giving the piece a half twist to keep it intact, he lays it aside, and resumes work on the next piece.

From the roughing three classes of fibre are obtained: the *longs*, which remain in the hand after the work is done; the *shorts*, which are retained in the hackle and dropped away; and the *tow*, which is composed of very short fibres. Though subsequently kept distinct, the shorts and the longs are counted as good fibre, and both are subjected to the same process; but the tow is put apart. A rougher can get through about 300 lb. per day.

Hackling by Hand.—The aim of every manufacturer is to employ machines in place of hand labour wherever possible. Roughing, however, still retains a place in even the most mechanical of factories, because the squaring of the ends demands intelligence which the machine cannot supply. Good hackling machines have been invented for the further process; but upon the highest classes of work and small portions of any class the hand hackler is generally employed.

The first tool of the hand hackler is called the *common eight*. It is fixed in the same manner as the hackle of the rougher, but is only 5 in. in height, and the pins are finer and closer. The method of working differs from roughing in several particulars. Having selected the piece, the hackler lays one end on the backboard of the hackling comb, and holds the fibres in position with his left hand; with his right hand he draws the flax down into the comb and pulls the fibre through. The action is repeated till the piece has been sufficiently hackled.

Ordinary kinds of flax, destined for medium-quality yarns, are finished off with what is called the *fine eight*, which is a hackle finer and closer than the common eight, but of about the same size. Higher grades, however, are treated with combs of delicate fineness, designated in trade parlance the *ten*, the *twelve*, and the *eighteen*. Only the very best flax can stand the last hackle, because, the action of the tools being to split the fibres and separate them from each other, the coarser flax would be split into fragments.

There is an art in hackling. In the hands of an unskilful worker the flax all goes to tow; that is to say, it is torn into fragments,

instead of being finely divided fibre by fibre. The skilled hackler can preserve every long fibre, leaving in the hackle only those which were originally short.

Machine Hackling.—Since the first hackling machine was devised, inventors have been busy, and now machinists offer to the flax manufacturer a large choice of machinery. The original form of hackler was a single cylinder studded with spikes, upon which the flax was hackled by being hung in holders fixed above it. One side only of the bunches of flax could be hackled at a time by those machines, and the holders were turned round to present the second side after the first was done. Describing a cylinder machine, Dr. Charley says: "The flax, divided into stricks, is spread out and placed between a pair of short iron bars, which are screwed together and hold it firmly, like the hand of the hackler. Each pair is called a 'holder', the screws of which are 4½ in. apart. A number of these holders are fixed to a cylinder at distances a few inches apart. The root ends of the flax fall upon an inner cylinder covered with sharp teeth, which revolves slightly and hackles the flax, while the outer cylinder revolves slowly in the opposite direction. When the holders have passed through about half a circle, they are deposited by the outer cylinder upon a kind of rail. The machine minder, generally a girl, then removes them to another machine similar to the first, where the uncombed ends fall upon an inner cylinder, and are hackled like the ends previously combed. Sometimes the entire process is performed by one machine, the holders being opened by the minder, after the root ends have been hackled, and the flax being turned the other way. To cleanse the points of the hackling teeth from tow, a series of brushes fixed upon wooden cylinders are provided; these brushes pass between the points and remove the tow."

Sheet Hackling Machines.—The machine most generally used, and the most efficient for all purposes, is Cunningham's sheet hackling machine. Though devised by Cunningham, the sheet hackler is made in all sizes by all the machinists who supply the flax-trade tools. This mechanism is so important that it is worth while to examine it in detail. After becoming acquainted with each part, we shall observe the machine in operation. The main working parts are the holders, hackling sheets, brushes and strippers.

Holders.—Each holder is composed of a pair of iron plates, 11 in. long and 4 in. broad, corrugated on the inner side, or covered with indiarubber or cloth. On the one plate is a bolt, and in the other is

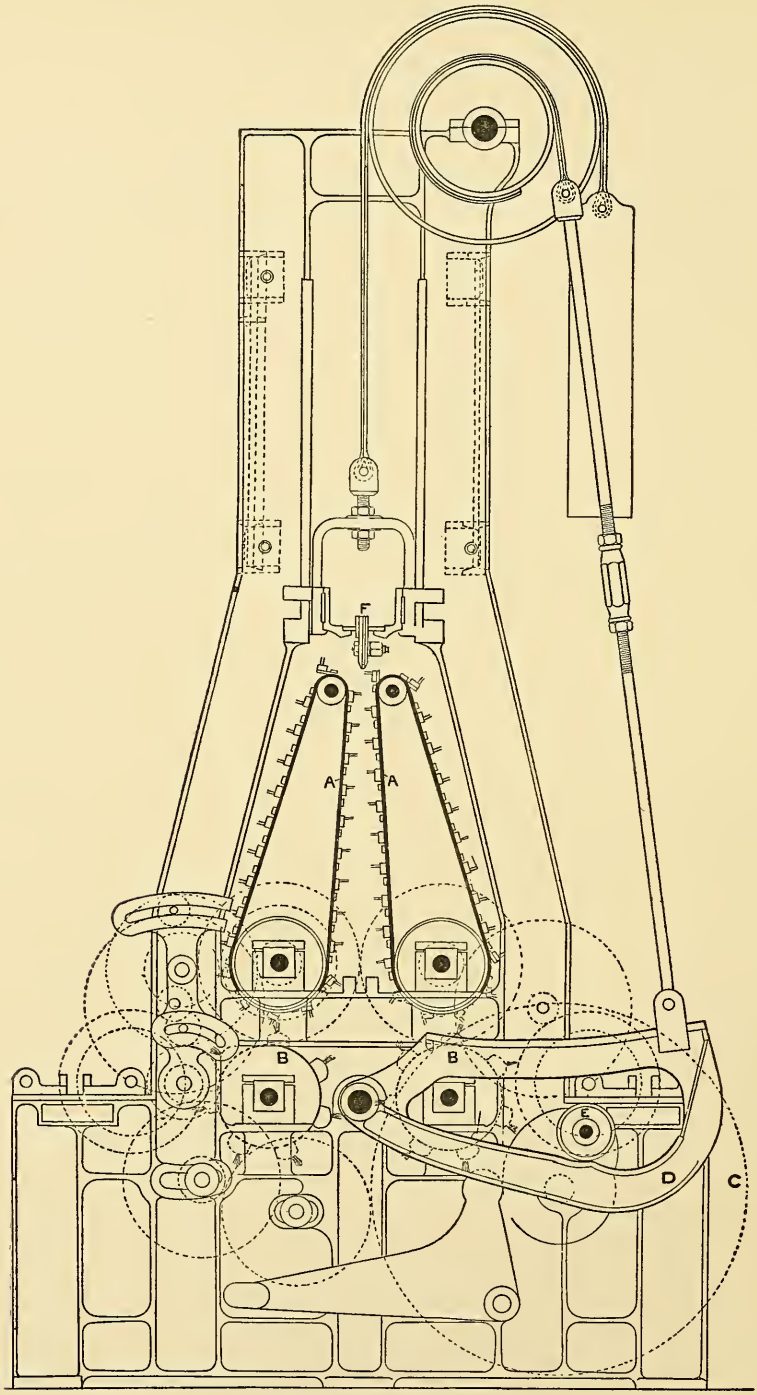


Fig. 56.—Hackling Machine

A, A, Hackling sheets. B, B, Brushes. C, Wiper wheel. D, Lever accomplishing the vertical traverse of the heads. E, Pin actuating the lever D. F, Holder.

a tapped hole for screwing on to the bolt, which is also secured by a nut on the outside. When the flax comes from the rougher, the boy "filler" takes two pieces and places one on each side of the bolt on the iron plate, so that the whole length of the root end of the flax hangs clear, excepting the 4 in. needed to cover the breadth of the plate. Over this the second plate is screwed and firmly bolted, clasping the fibres as in a vice. The grip of the plates is aided by the inner corrugation or covering we have mentioned. Now filled, the holder is placed in the head, or holder channel, on the top of the machine. The holder channel is a bar which, besides having a vertical traverse of the length required by the length of the flax, has also a lateral traverse equal to the length of the holder. A horizontal lever, working on a centre stud, accomplishes the vertical traverse of the heads. A strong iron pin is fixed in the side of the lever at a short distance from the stud. A runner, cast in the groove of a large wheel called a wiper, encircles the pin, being raised or lowered according to the direction of the groove by the revolution of the wheel. As the fixed pin of the lever is contained in the runner, the rocking motion is conveyed to the lever, and through its agency the head slides are raised and lowered. The lateral traverse is also effected by the wiper wheel, on the outside of which another groove is formed, containing a runner. This runner acts on a curiously shaped vertical lever, bifurcated at the end, with a V-shaped bend in the middle held in position by a stud fixed in a bracket set in the frame of the machine. On the bifurcated arms of the lever, rods operating a set of pawls are fastened. Each pawl, or detent, works on a holder in the channel, and they are adjusted so as to draw the holders when the head is at the end of its upwards traverse. By these movements one holder is passed out of the head at every up-and-down movement of the holder channel. Or, to put it differently, each holder is moved forward its own length at every vertical traverse and comes within the grip of another set of hackles, the end one, of course, moving outside. The holder channel extends beyond the head of the machine and keeps the holder in position. The attendant lifts it off before another holder comes along. This attendant is called the "changer", because of his office. He has already laid within a bed a pair of holder plates, the depth of the bed being proportioned to the length of the flax. Dropping the combed end of the fibres into the holder, he screws the plates up; then he loosens the holder from the end which has yet to be hackled. By this simple means the flax is placed exactly in the proper position for being

hackled once again. The holder is placed on the holder channel and begins its course once more.

Hackling Sheets.—The hackling sheets are sets of iron bars fastened on endless leather straps, about 5 or 6 ft. in circumference. Upon the iron bars the hackling stocks are screwed in sets of from eight to twelve, according to size or fineness of the machine. Hackling machines designed for coarse work generally have eight tools on the length of 12 ft. The tools are graded from coarse to fine along the length of each bar. The hackle stocks are screwed firmly on the inner sides of the bars. As all the bars are secured to the leather straps at the ends and in the middle by screws, they form together an endless sheet of hackling combs.

In the machine the sheet is stretched between two rollers, one above the other, at the distance required by the stretch of the sheet. The lower roller, which is driven by power, is about 9 in. in diameter, and equipped with catches at the ends and the centre to lift the bars round with its own revolution. The upper roller is merely a carrier, stretching the sheet; but it has also other and important functions to perform. In every machine there are two sheets of hackling bars, and upon the mutual adjustment of the sheets greatly depends the degree of hackling to which the flax is subjected. Each upper roller is fixed in bosses which have adjustable screws, to lift or lower the roller as required. If the sheets are to hang almost vertical, and therefore scarcely allow the hackles to intersect, the screws are elevated; if a heavy sag is to be given to the sheets, the upper roller is lowered. It will be obvious that the setting of the sheets calls for very careful work. The two sheets revolve in upon each other, and therefore draw down against the flax hanging between them, on the holder channel, or head.

Brushes and Strippers.—Flax, as has been pointed out, is a gummy material, and the teeth of the hackles, unless we are very mindful, become clogged with the material which has been drawn out in the hackling. The oldest instrument for cleaning the hackling bars from tow and gum was the *brush and doffer*. This apparatus consisted of a revolving brush constantly playing on the bars at the foot of the sheets, and a doffer brush, which took the material from the brush and deposited it in a long box below the machine. The brush and doffer was found inefficient, inasmuch as it only cleaned one side of the teeth; therefore another apparatus was devised, consisting of stripper rods. The rods are plain strips of wood, tough and flexible, about 1 in. square, and long enough to extend the length of

the hackling bars. We have noted the bosses on the driving roller of the hackling sheets. The inventor of the stripper rods had noted them too, and determined to make use of them. He cast on the inner sides of the bosses grooves for the reception of the stripper rods, and on the ends of the rods fixed iron ends to fit the grooves. The rods being fully the length of the distance between boss and boss, they are bent to be inserted, and the return spring holds them in position. Turning with the roller, the stripper rods come into contact with the hackling pins and drag away the tow from them as they pass. The stripped material drops into a box below.

Employed alone, the stripper rods are too weak to deal efficiently with strong and gummy flax; their action is too loose. It was realized that some supplementary appliance was needed, and Mr. R. W. M'Dowell, of Belfast, devised a very effectual apparatus which he describes as follows:—

"My invention is applicable principally, but not exclusively, to those hackling machines in which vertical sheets and stripper rods are employed, such as those known in the trade as 'Horner's stripper rod'. It may be attached to other makes of machines. My invention substantially consists in the application to such machines of a revolving brush, the motion of which is capable of being reversed so as to clean itself. For this purpose I provide, preferably, a spiral brush, which revolves in the same direction, and quicker than the pins of the machine, so causing the brush to pass through the pins and remove any gummy or fibrous particles adhering to them. At regular intervals, say when the head or channel of the machine rises, the brush is made to reverse its motion and slowly revolve one or two times in the contrary direction, thus meeting the pins and allowing them to carry away any fibre that may stick on the brush, which fibre is deposited with the tow. By means of this improvement the pins are kept cleaner than by what are called the brush and doffer machines, as in the latter the brushes only clean the back of the pin, leaving the cutting side dirty; but, by the use of my invention, all the cutting parts of the pins are kept perfectly clean. I am aware that the revolving brush is not new, but as applied to the stripper-rod machines, and reversing as aforesaid, it is claimed to be new. The gearing mechanism for producing the reverse motion of the brush may be varied, but a convenient arrangement, and such as I have found to answer, is as follows: There is a wheel on the end of the bottom shaft of the machine driving the sheets, into which wheel works a small

pinion with clutch gear and loose on the brush shaft. The corresponding clutch slides on a key in the brush shaft, which latter has a wheel fast on end of brush shaft, and working outside the wheel on the bottom shaft and pinion. There is another wheel fast on a socket working on a stud fastened to gable of machine, and is geared with wheel on the brush shaft. On the same socket there is also a loose wheel with clutch, the corresponding clutch sliding on a key in the aforesaid socket, and the latter wheel is in gear with the wheel on bottom shaft. The two sliding clutches are worked by a small lever or rod working on a pivot equidistant from each other. When the clutch is fast in the pinion the brush is driven with the pins; but when the head lifts, the lever, which may be fixed either to the head or to the tow catcher, throws out the clutch and throws in the other, which causes the loose socket wheel to become fast on the socket, and as the corresponding socket wheel is fast on the same socket, it revolves in the same direction; the wheel on end of brush shaft being in gear in the first socket wheel causes the brush to revolve in the opposite direction from what it did in the first instance."

According to the general testimony of the linen trade, this appliance works well and effects the purpose for which it was designed. It admittedly adds to the complexity of the machine; but that is a trouble which could hardly be avoided.

Working the Hackling Machine.—Attention is first given to the setting and gearing of the machines. In an ordinary linen factory there are three classes of machine—the coarse, the medium, and the fine; some factories employ four, two on long line, and two on cut line. Before starting any machine several particulars have been determined upon. The hang of the sheets rules the degree of intersection of the points of the hackle pins opposed to each other. By means of the screws on the sockets of the carrying rollers, the hackling sheets are placed in position and the rods set plumb, the latter point being very important. The rise and fall of the heads, bearing the holder channel, is set to a given number of revolutions of the sheets. On the machines for coarse flax the heads are given 6 lifts to 20 revolutions of the sheets, on which the finishing tools are 8 pins to the inch; medium flax is hackled on a machine with 5 lifts of the head and 15 revolutions of the sheets per minute; and fine fibres are worked at the rate of 3 lifts of the head and 10 revolutions of the sheets per minute, on a machine with finishing tool 50 pins to the inch. These adjustments are only rough approximations; in practical work some latitude

is taken. Our point is, that there is a definite relation between the three factors, the head, the sheets, and the tools.

Each parcel of flax from the rougher contains both the longs and the shorts, though clearly separated. The shorts are taken in hand first, and then the longs, each batch of 2 cwt. being marked specially so as to be readily identified.

Now the filler lays two fingers in each holder. Screwing the plates tight, he puts them up on the holder channel one by one, the machine going the while. If we were to fill the holder channel before starting the machine, the endmost holder would be immediately ejected. Moreover, the flax would only be combed by the finishing tools and torn to pieces. When in full working order, the machine has long tresses of flax hanging down from the head in the very middle, and between the hackling sheets.

Observe the motions of the hackling machine. The head comes down, while the hackling sheets, bearing each its serried rows of hackling pins, revolve with a quicker motion, the pins dragging at the descending flax tresses. The head lifts again and draws up the fibre, the hackling sheets still pulling downwards, combing out the dependent lint. With every lift the shifting apparatus draws along every holder its own length, bringing it into position for being hackled by a different set of tools fixed in the horizontal rods of the sheets. At the same time the stripper rods and clearing brushes are working, cleaning the pins of the hackling sheets, and depositing the rejected tow in the box. As soon as a holder comes out on to the projecting end of the holder channel, drawn there by the detents, the changer lifts down the holder and proceeds to turn the flax. At the other end the filler inserts another holder full of unhackled flax. In this manner the work goes on constantly, till the whole of the fibre has been hackled, or a stage in the hackling has been accomplished. When both ends have been treated, the flax is ready for the next machine.

Hackling is anxious work. The machines are combinations of very delicate and very heavy appliances, with a certain amount of play in all the principal parts which renders them ready to go out of balance. Flax gives off a lot of dust, and grit, if allowed to gather in the parts, destroys the efficiency of the machine.

The finished flax is made up into parcels of 10 lb. each, named *tipples*, by attendants, usually boys, who are technically designated *tipplers*. The boys go constantly round the hacklers, taking from each the tipple he has finished. When a parcel is hackled, the tipples

and the tow are weighed, the combined weight showing how much waste has been made in the process. Tow and line go different ways, the one to the dressing department, and the other to the carding machines with all the rest of the tow.

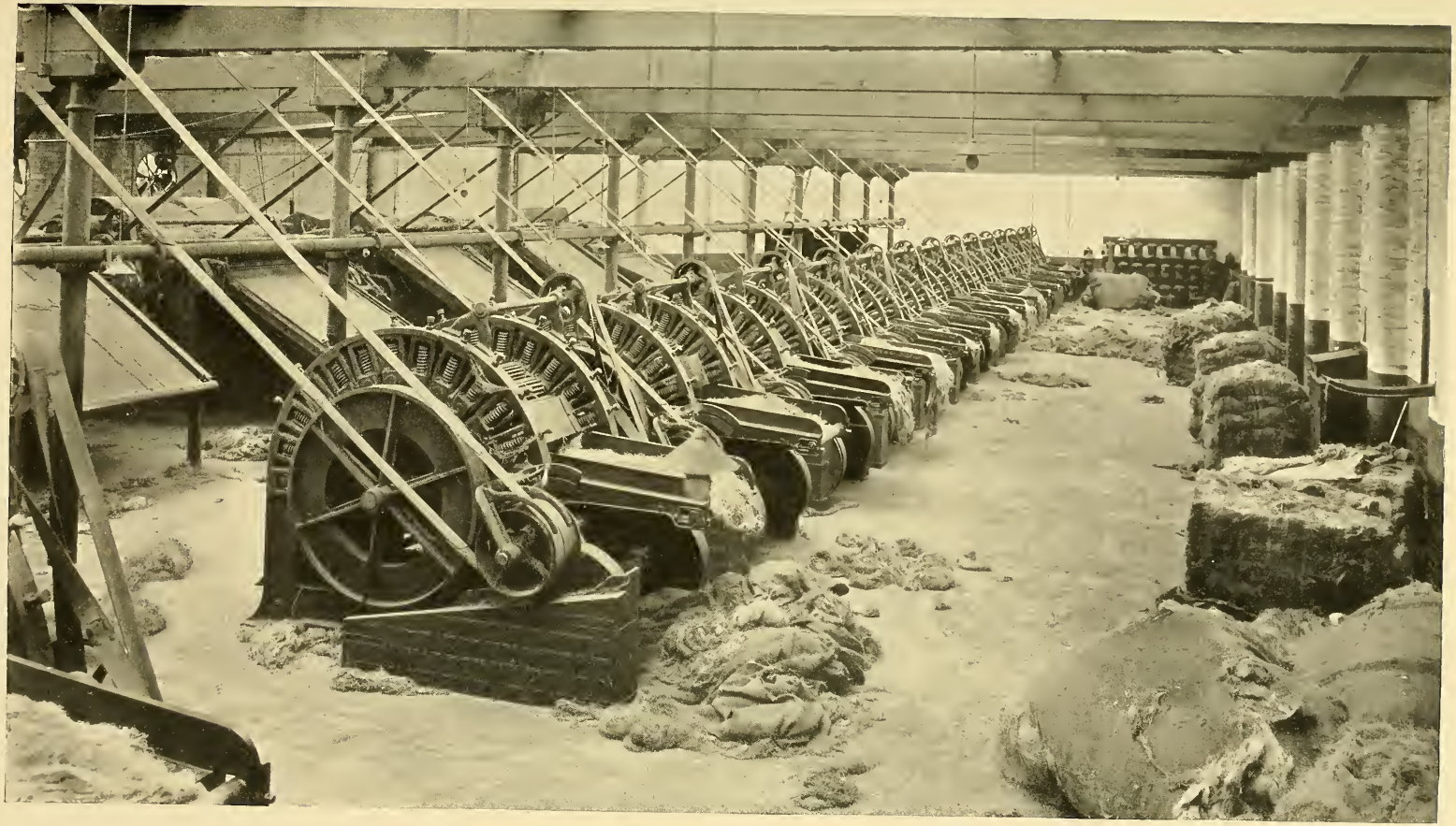
Dressing and Sorting.—Another hand operation intervenes at this point between one mechanical operation and another in the linen factory. As before, the amount of hand labour employed depends on circumstances. In some factories special hand dressers are employed, who make the flax ready for the sorters; in others the hand worker is both dresser and sorter, the main part of the dressing having been done on machines. The latter case being the most common, we shall take it as the practice to be followed.

All kinds of textile fibres require to be classified according to fineness and quality. Mixing may be resorted to, but the mixing is always intelligent, not haphazard. Having first discovered what kind and quality the given masses of fibres are, we can mix them as seems to us good. Though from the beginning a system of classification has been carefully followed, new differences are revealed after each operation. The hackling machines have discovered the essential qualities of the flax.

From the weighing room the parcels of line are brought and given over to the sorter, whose bench resembles somewhat that of the rougher. Upon it are two hackles, one coarse and one fine, and the touch pin. The sorter, having spread out a bunch, selects the fibres according to quality, drawing the flax swiftly through either of the hackles, or both, to lay them even, and works them on the touch pin to square the ends. Upon the table or bench a number of boxes are ranged, labelled 2 lb., 3 lb., 4 lb., 5 lb., and so on, according to an old system of comparing fineness with weight. Into these boxes the sorter casts the fibres picked, all the flax of one quality being placed in the same box.

Only workers of experience and ability can be trusted to sort the higher qualities of flax. Fineness, strength, closeness, and colour are the attributes which fix the class to which a flax fibre belongs. These vary in many degrees, and delicate touch, quickness of eye, and the knowledge born of experience are needed for the work of sorting.

Sorted flax takes on a special character. It is the raw material of the linen spinner. It is stored for him in bundles or boxes, each class separate. When a given yarn is to be made, the flax of which it is to be constituted is taken from the stores, either a pure quality or



HEMP AND RAMIE SOFTENING, BLOOMFIELD MILL, BELFAST

(Belfast Ropework Company, Ltd.)

mixed of various qualities in various proportions. Some kinds of flax lie in the stores for months, and other kinds are not stored any time.

The Treatment of Hemp.—The fibres we call hemp are derived, as we have seen, from various plants grown in regions far apart. *Common hemp* has the appearance and quality of a coarser, woodier flax; *Manila hemp* is thicker in the fibre on the average; *sisal hemp* is very similar to Manila, but scarcely so fine and strong; and all the

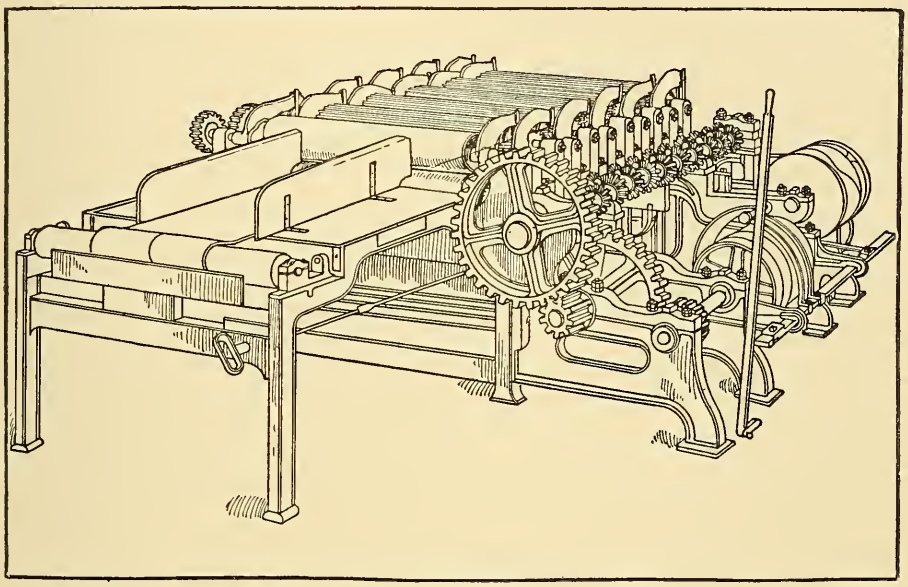


Fig. 57.—Hemp-softening Machine

other hemps partake sufficiently of the flax character to render similar treatment in manufacture almost inevitable. Hemp is the raw material of twines and ropes; some portion of the fibre is employed in the making of coarse cloths, but the quantity is very small. In any case the hemp so utilized is treated exactly as if it were coarse flax.

Hemp Fibre Softening.—The hard character of hemp causes it to be troublesome to work, with consequent loss of time and material. Flax growers, in preparing their fibres for the market, employ a machine known as the *breaker* to break down the woody boon without injury to the valuable fibre. With slight alterations, this machine could obviously be made to soften hemp, and manufacturers of twines and ropes were not long in finding this out.

Several kinds of hemp softeners are on the market and in use.

The idea is to work the fibres between pairs of fluted rollers in such a manner as to gently break down their stiffness and render them tractable. One very simple hemp softener (fig. 57) is a series of horizontal rollers, fluted and placed on a level, geared to a reciprocating drive at the side of the machine. The rollers turn with a rocking motion, and work upon the fibres in a gentle and effective manner.

A more complex softener is built of fluted rollers set together in cylindrical fashion, with springs on the sockets of the rollers and a reciprocal drive. "The machines have fourteen pairs of rollers, and are fitted with a reciprocating motion to give a backward-and-forward movement to the rollers. The material is laid on a revolving sheet, which feeds it into the first or coarsest pair of fluted rollers, and then passes it on to each of the succeeding pairs in turn, until it reaches finally the last and finest pair, where it is delivered on to the floor."

Taken from the softeners, the hemp fibres are treated in the same manner as coarse flax.

CHAPTER IV

The Preparation of Jute and Ramie

Jute Manufacture in Britain.—The centre of jute manufacture in Great Britain is the Scottish city of Dundee, situated at the mouth of the River Tay. The story of the coming of jute to the northern town is interesting, and shows what a power one man may have over the fortunes of a great community and the development of an industry.

Unobserved by Western nations, the people of India grew, reaped, spun, and wove the jute fibre till near the close of the eighteenth century, when an official of the East India Company, struck by the great size of the fibre, called the attention of his superiors to it. Very little appears to have been done immediately, but a few samples having reached this country, and causing enquiry to be made, the East India Company began to bring over considerable quantities of the fibre about 1815. The size, woolly appearance, lustre, and evident cheapness of the new fibre created a very strong impression, and many thought that it would prove a vegetable substitute for wool; but a few experiments thoroughly dissipated the high hopes built upon jute. Treated as wool, it revealed a harshness and intractability, combined with tensile weakness, which put it quite outside the woollen factory; in the flax factory

the fibre also failed, for a variety of reasons. A strong hostility, latent before, became active against the introduction of the fibre in any shape or form. Linen and woollen yarn merchants expressly stipulated in their contracts that no jute should be put into the yarns supplied to them. Proposals to mix even carpet yarns of the lower grades with jute were not entertained. For about five years the East India Company continued to send parcels of jute fibre to various textile centres, and experiments were frequently renewed; but the samples ceased to be taken note of and the fibre was almost forgotten.

One fact, however, kept the fibre in evidence. Cottons and other dry goods imported hither from India were packed in jute gunny bags. A Dundee linen manufacturer, named Watt, observed this, and thought that if the Bengalis could make up the fibre so cheaply, there was no reason why it should not be done in this country. At the time, about 1832, cotton bagging was in large demand, and the hint of the gunny bags fitted in to a nicety. Mr. Watt made up his mind to try what could be done. He was a practical inventor, a man devoid of theories, but an indefatigable experimentalist, and that was the kind of man required for the undertaking. Jute would not go through the flax machines because of its great length; Mr. Watt broke it down to short lengths. Even then the spreader and the common tow carders wasted and broke it, instead of opening and smoothing it; therefore the inventor devised a different kind of carder, in which the large fibres were drawn apart and unravelled by appropriately long teeth.

The practical character of Watt's inventive genius was exhibited in the method he adopted to overcome the natural harshness and flyaway habit of the jute fibre. Dundee is a whaling port, and whale oil is a commodity familiar to all the inhabitants of the city. In his practical way Mr. Watt sprinkled whale oil over the jute fibres to render them ductile and cohesive. Success attended his experiment.

Before many years jute became the chief manufacturing product of Dundee, and an important branch of textile manufacture. The greater number of factories are employed in making hessians, coarse cloths for sacking, and like purposes; but the usefulness of the fibre is being gradually extended. Jute yarns are in considerable demand for certain kinds of carpet warps, the filling of tapestry and velvet-pile tapestry carpets, and for doubling with woollen yarns of coarse grade. The trade in jute mats and rugs and fancy wares, though limited in extent, is rapidly growing, in response to an ever-increasing demand for cheap commodities of that class. As at present manu-

factured, jute is the cheapest of all fabrics and seems likely to gather importance on the market.

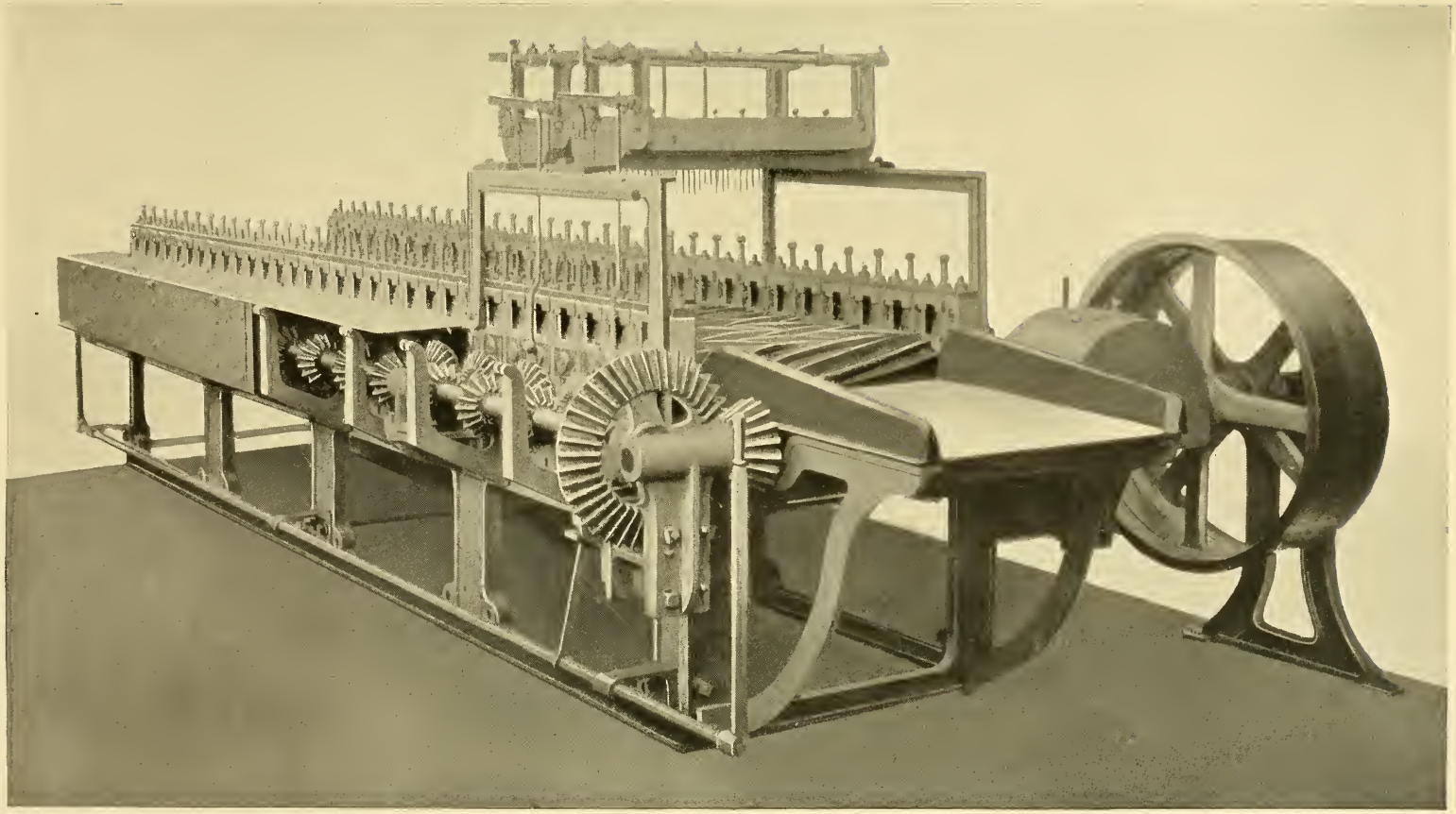
Rather more admirable, from a textile point of view, are the experiments which have been directed towards enhancing the textile value and status of the fibre. By a modified process of hackling and gilling jute has been finely subdivided and made fit for spinning into fine yarns capable of being woven into cloths of fine and close texture. The capacity of the better qualities of jute for higher service has been amply demonstrated, though it has not been fully subjected to the test of the open market. We think it right, however, to draw attention to the fact, as a mild corrective to that pessimism which constantly sees in the temporary scarcity of one fibre the threat of a textile famine. The resources of the textile industry are wholly beyond computation.

The Process.—Excepting raw silk alone, no fibre passes through a preparatory process so short as jute. This is due, for the most part, to the rough and cheap class of fabrics into which it is woven. The fibres are softened, oiled, carded, and formed into slivers for the spinner.

Classes of Jute.—The fibre arrives at the factory in parcels weighing about 400 lb. each. The qualities of jute range from Sirajganj and fine Desi to coarse Bhatkal. Before commencing work, the manufacturer selects the fibre he intends to spin. Every parcel is marked, showing the kind and quality of fibre it contains. Selecting the parcels required, the workers open them out, and make up the fibres into small bunches or stricks for feeding to the softeners.

Jute Softening.—As now operated, jute softening includes two processes, which were formerly separate. Softening and oiling are now accomplished upon the one machine. *Batching*, as the oiling operation was named, is still practised to a limited extent; but the rule is to place an oil-spraying machine over the softener, and get the whole process through at once. As has been said, jute in its raw state is difficult to work because of its great size and because of its harshness and intractability. The aim of the softening operation is therefore obvious.

The original softening machine was a huge piece of machinery. Being a serviceable tool, it is still used in some factories, though admittedly inferior to the newer models. Four rows of rollers, ten in each row, are held, one above the other, in the slots of a strong frame. The frame supports the rollers, but they are so arranged that the weight of the top roller rests on the second below, the second on the third, and all three on the fourth. The rollers are deeply fluted, 9 in. in



JUTE SOFTENER

(Thomas Larmuth & Co., Salford, Manchester)

diameter and 2 ft. 6 in. long. At the fore end of the structure is the feed lattice, and under it a pair of drums round which revolves an endless band the breadth of the rollers, to keep the fibres going through the machine. On the back of the machine another pair of drums and an endless band perform the same office, while the bottom drum of the pair acts with the single roller at the very end of the structure in drawing off the softened fibres. On the head of the softener is fixed the oiling apparatus, consisting of two cisterns, one of oil and one of water. Within each cistern revolves a roller, dipping half its diameter into the fluid, the upper half coming into contact with a slanted knife. Over these knives the mixture of oil and water runs down in a smooth and slender stream on to the fibres passing through the rollers below.

Fed on to the lattice on a level with the point of contact of the highest and second-highest row of rollers, the fibres pass into the grip of the softening flutes, and are carried on to the end of the row, where the endless band turns them down on the top of the third row of rollers. Passing along between the second and third range, the jute is carried on to the top of the fourth row of rollers, with the weight of the other three sets of rollers pressing down upon it, while the edges of the flutes on the cylinders act in conjunction with the dripping oil and water to render it soft and flexible. Having traversed the whole length of the machine, the fibre is caught between the single fluted roller and the plain drum at the end, and dropped on to the floor.

The softening machines most in use at the present day are much lighter and simpler than the above. The rollers lie in pairs in horizontal succession, and they are driven with a reciprocating motion. The machines are of various sizes, some having thirteen pairs of rollers and some eighteen pairs. The shapes of the corrugations are also varied. Some put faith in the old form of simple fluting; but others favour corrugations, diamond-shaped, spiral lines, and slanted flutings. The form which has been generally accepted, however, is a finely elongated spiral fluting. On the axles of the rollers are fixed small pinion wheels, and these fit into the pinions on a long shaft driven from a cog and pinion on the shaft of a driven pulley. By the movement of this rod the rollers are given a reciprocating motion, very serviceable in softening the fibres. This machine, like the other, has an automatic feeding apparatus, by which the fibres are put into the machine. Having passed into the grip of the first pair, the fibres

are drawn through one pair after another and delivered at the end fully oiled and softened; for, of course, it is understood that, when desired, it is easy to fit an oiling plant over this machine.

Though the softening operation seems very simple, it is not free from difficulty. Obviously, careless feeding would be apt to upset the balance of the softening machines. A double layer of fibres fed in at one point, and a thin layer put in at another point, would not only produce defectively softened jute, but also injure the rollers. A frequent source of trouble is the rubbish sometimes found in the fibre. Hard substances break the edges of the flutings and render the rollers useless. Jute softening, like every other textile operation, demands some skill and a very considerable amount of care. The operative is only a machine minder, but he or she is required to exercise more than mechanical intelligence. This is a fact too frequently overlooked both by operative and by employer.

Oiling and Batching.—When the oiling apparatus was first introduced it seemed for a time that separate oiling and batching would be wholly abandoned; but a reaction, led by the manufacturers of the highest classes of jute cloths, set in, and the two methods are now practised side by side. It is necessary, therefore, to note the older practice in some detail. Mechanical oiling on the softeners is not so thorough as oiling by batching, and wastes more oil. After being taken from the softening machines, the fibres are laid down in thin layers, one on the top of the other, so as to form a square stack, and each layer is plentifully sprinkled with an oily mixture. Manufacturers have their own favourite recipes for compounding the mixture. The simplest compound is equal parts of water and whale oil, and this serves very well for coarse jutes oiled on the softening machines. The nature of the oiling mixture is of some importance, however, to the finer kinds of fibre. A mixture highly recommended is as follows: ½ gal. whale oil, ½ gal. seal oil, ½ gal. mineral oil, 5 to 7 gal. water; mix and heat to 90° F. This is sprayed over the layers of the batched jute, or from the oiling apparatus on the softening machine. When batched the jute is left to season for a day or two, care being taken that the stacks do not heat.

Ramie, Rhea, or China Grass.—Since ramie is a comparatively new fibre, its manufacturing process has not yet been systematized. In the early preparatory operations especially, system has hitherto been impossible. This is because of the essentially diverse nature and condition of the fibre supplied. So pronounced is this diversity

that, for a long time, China grass was regarded even by experts as a fibre of a different kind from ramie. It was only after investigation that the similarity of the plants from which the fibres are derived was discovered. In its natural state the ramie bark is permeated by a viscous fluid, which, when allowed to harden in the fibres, renders treatment of them exceedingly difficult. The sole difference between China grass and ramie was the comparative cleanness of the former from the gum or viscous fluid. In stripping the fibres from the stems the Chinese have a method of drawing the bark against the edge of a blunt knife, and pressing out the gum when soft; the ramie growers in India, on the contrary, simply strip off the bark and let it harden. When hard, this gum is peculiarly adhesive, and the only way of getting rid of it is by a series of chemical operations. China grass needs chemical treatment, and ramie, of course, needs much more. If it were possible to induce growers to undertake degumming themselves, while the fluid is soft, a great saving in labour and costly materials would be effected. If, by merely drawing the strips of bark through under a blunt knife pressed down on a block of wood, the Chinese can clean away nearly all the gum, a very little more, combined with thorough and repeated washings, would achieve the purpose. In the present state of affairs the general principles of the preparatory processes alone can be laid down.

Ramie Manufacture.—Till near the close of the nineteenth century ramie manufacture could hardly be called an integral part of the textile industry. Small and struggling firms here and there, and large firms aside from their ordinary business, were making experimental efforts to exploit the fibre; but no cloth was sold on the market as ramie cloth. This, after all, is the practical test, and the fibre which fails commercially is of little interest to the textile worker or merchant. At the beginning of the twentieth century, however, light cloths made wholly of ramie came on the market and won a measure of public favour. The rivalry of these fabrics was directed against linen, spun silks, and woollens of open texture. Several factories were built and equipped for the manufacture of ramie, and the demand for the fibre was greater than the supply.

Ramie as a new fibre has great possibilities. It has been made into ropes and twines, threads and yarns, sheetings and canvas, plain cloths and fancy cloths, incandescent mantles and lamp shades. On the one hand, the fibre has been set up as the rival of long wools, and

on the other hand it has been found a very good substitute for hemp. These facts belong to the future as well as to the present; otherwise we should not record them here. Ramie has long to wait before its place in the textile world has been defined.

Course of Preparation.—The preparation of ramie for the spinner is a long process, carried through in several ways. The course most commonly adopted is as follows: 1, degumming; 2, preparing, or oiling; 3, softening; 4, filling; 5, dressing.

Degumming.—The bales of ramie are opened out, and the fibre is sorted into batches of various qualities. Sorting, in this case, does not require much skill. Length, colour, and cleanness are the standards of quality. The highest class is composed of those fibres which show a long, clean filasse, lustrous, clear, and sound; the lower kinds are graded according to the degree in which they possess these attributes.

The degumming process is chemical, involving the use of much water and quantities of strong chemicals. The object of this series of operations is to decompose the gummy substance, bleach the fibres, and wash out the strong acids which have been employed. It has been already hinted that the condition of the fibres largely determines the nature of the degumming process. Roughly speaking, the fibres from India require longer and more drastic treatment than those from China. The following are the stages of the process adopted for Indian fibres:—

1. Steep the fibres in a bath of strong soda lye, to clear away all the dirt and extraneous matters.

2. Having prepared a bath of hydrochloric acid, lay the fibres within it. As this is a strong ferment, with a retting action, it must be carefully watched, lest injury come to the filasse.

3. Steep again in strong soda lye.

4. The viscous gum has now been slightly softened, and to remove it we employ a powerful solvent in the shape of a bath of permanganate of potash.

5. The burning liquid must be taken out of the fibres as quickly as possible. Hyposulphite of soda washes out the permanganate. To assist, however, in dissolving any gum which may remain, we add to the bath of hyposulphite a quantity of hydrochloric acid and work the fibres through the mixture.

6. Give the ramie a bath of hyposulphite alone.

7. The hyposulphite of soda should have cleared away the last

traces of the permanganate and the substances it destroyed, and now by applying a weak solution of hydrochloric acid we can dissolve even the germs of gummy substance remaining.

8. The last is a washing operation, pure and simple. Steep the ramie in soapy water for a time. Wash thoroughly. Dry in the centrifugal extractor or other drying machine.

To carry through the foregoing process properly the manufacturer must provide himself with a full equipment of kiers, vats, and other appliances, as well as a plentiful supply of water. The makers of bleaching machinery undertake to provide all the appliances necessary for the work.

Another Degumming Process.—The treatment given to China grass, or ramie fibre imported from China, is much less drastic than the above. Comparatively clean and partially degummed, the fibre comes out a fine filasse from the following process:—

1. Boil the fibres in a solution of soda lye for about seven hours, then wash in water.

2. Prepare a solution of chloride of lime and steep the ramie in the liquid for ten hours.

3. The fibres by this time are partially bleached and the gum has been softened. To decompose the gum completely, however, it is necessary to subject the fibres to a form of retting. A very suitable retting agent is a solution of sulphuric acid mixed with oil of vitriol.

4. When well retted, without injury to the fibres, the ramie is taken out and washed clean.

Comparison of the two preparatory processes will show the enormous advantage to be gained by degumming the fibre while yet green. If ramie were degummed as soon as gathered its value would be greatly enhanced. Not only would the process at the factory be shortened, but the fibre would gain in quality. Chemical processes so drastic are bound to have a deteriorating effect on the fibre, no matter how carefully we may go to work. Under ordinary conditions, and with the average ability of the worker, accidents occur. Traces of permanganate in the first, and sulphuric acid in the second process, may remain with the worst consequences. The retting may easily be carried too far, without the fact being detected till the goods have gone out to the world. One draper on whose shelves the ramie goods have rotted could do more to damage the reputation of the fibre than years of success would eradicate.

Preparing or Oiling.—Under the most favourable circumstances the ramie fibres are left dry, harsh, and bare by the chemical process; the acids are very strong and rasp up the fibres. To clothe the naked fibres again, and render them smooth and soft, we sprinkle them with a kind of oily substance. This substance should be of fine consistency, yet free from clogginess. A quickly flowing oil would run off the hard fibres. A mixture which has given good results is made up in the following way. To 15 gal. of water add 200 gm. glycerine, 200 gm. Castile soap, 100 gm. white wax, and 50 gm. tallow. The water should be kept at boiling point while the ingredients are stirred in. The fibres are put down in layers, and each layer sprinkled well with the liquid, which is given time to spread and sink in.

Softening.—Some variations in practice occur at this point. In many cases the fibres are taken directly to the filling room and passed through the filling engine. The best practice, however, is to treat the ramie on a softening machine, whatever the after-processes may be. Ramie is a fibre totally different in many respects from flax and jute, the softening operations and machines of which we have examined. Flax is a solid fibre for all practical purposes; ramie is a hollow, hair-like tube, the walls of which vary in thickness. To employ deeply fluted rollers on such a fibre would be a mistake. The ramie softener is therefore of special construction, the rollers pressing the fibres with a smooth and oscillating motion, softly breaking down the hardness without bruising the surface of the material. In other respects the working of the ramie softener differs little from the others. The stricks of fibre are fed on to the feed lattice and pass through the machine, issuing soft, flexible, oily, and lustrous.

Filling.—Though smooth and hairlike, with very little cohesive tendency, the fibre has passed through processes which have done nothing to disentangle the original matting of the stricks, but rather accentuated the defect. We have also to take into account the fact that smooth and strong fibres knot more firmly than soft and flexible fibres. Various machines have been devised to draw out the tangled stricks of ramie without too much breakage and consequent waste, and at a cost as small as possible. Flax hackling was tried and found altogether unsuitable, because of the amount of breakage incurred. A looser, softer machine was needed. The waste-silk industry was already using an engine called the filling engine, which, in a modified form, seemed to meet the demand better than any other in the opinion of

manufacturers. After some experiment it was found that more perfect results were obtained on the series of machines employed by the worsted manufacturer. When we consider the gilling and combing machines we shall again refer to the matter. Meanwhile it should be observed that ramie must, in that case, be placed in disadvantageous competition with the highest classes of wools. Theoretic partisans of the nettle fibre claim that no elaboration of treatment is too good for it, and that it amply repays the costliest operations. Practical men, however, have learned a different lesson; they know that the most direct and cheapest way of getting a thread is the best, so long as the thread can be made to serve in cloth manufacture.

Ramie Filling Engine.—The object of ramie filling is to make the fibres lie evenly together and parallel with each other. In the case of nearly all other bast fibres we have a much easier task, because the fibres have been kept in a comparatively parallel condition all the time, with rooty ends all lying in one direction. The ramie fibres have been tossed about and tangled. Consequently hackling is out of the question. The masses of material must be loosely held while they are being drawn into straightness.

The most conspicuous feature of the filling engine is a large cylinder on the back of the machine, like a large drum, from the surface of which rows of spikes stand out at intervals of 3 or 4 in. The middle part of the engine is occupied by a series of alternate spike-covered rollers and roller brushes, each set being driven independently. In front of all is the feeding band or lattice. (See p. 39, fig. 58.)

The fibres are laid on to the feed lattice and carried up to the first spiked roller, which winds the material round itself. A brush roller, with doffer, works behind the porcupine roller, as the first is named, and drags off the fibres. Another spiked roller, running at higher speed, next takes hold of the ramie and gives it another pull, to be dispossessed in turn by the same agencies as before. As the fibres come on through the machine they are brought within the grip of the long spikes on the surface of the large cylinder, and then row after row of points pull off the fibres, clothing the drum with them. When as much fibre as it can hold is on the drum, it is stopped and the ramie cut into lengths the width of the spaces between the rows of spikes. The filler thus obtains small bundles, or stricks, of straight and parallel fibres.

The defects of this engine, from the ramie manufacturer's point of view, are obvious. It is better suited for dealing with a fine and

flexible material like waste silk. For one thing, a conspicuous merit of ramie is the length of its filaments, but here the whole fibre is reduced to lengths of 3 or 4 in. For many purposes the engine serves very well, however, and it is accepted by numbers of spinners.

Dressing.—Originally invented for the waste-silk industry, the dressing machine (fig. 59) completes the work of the filling engine on ramie in the process at present followed. It is an ingenious contrivance and worthy of detailed study. Stretched between two rollers, one at each end of the long machine, is a broad endless band, and upon this band, at short intervals, are fastened flat combs, containing regular rows of short pins. On the bed of the machine, over which the broad band travels, a series of holders, technically named *books*, are firmly fixed with movable clamps. Lifted from the bed, the books are filled with the stricks of ramie, clasped, and then clamped down on the bed of the machine. When the machine is set going, the combs on the endless band come round and act on the fibre in the books, pulling away the short fibres and combing out the long ones. The ramie remaining in the clasp of the books is taken out and put aside in a class by itself; the fibres in the combs are cleared out and put once more in the clasps on the bed of the dressing machine. The combs again go round, drawing away the shorter fibres and combing clean and straight those which resist the dragging force. The action may be again repeated, producing what are named second and third drafts, leaving a remnant of fibres classed as noils. From the dressing we may thus obtain three or four qualities of ramie, judged by length of fibre. These classes may be mixed in the processes following or kept separate, according to the kind of yarn to be spun. The noils are put aside in a class by themselves.

CHAPTER V

The Preparation of Silk

Silk.—The standard of textile excellence is silk. What gold is to metals, the diamond to precious stones, silk is to fabrics. Most precious and beautiful of cloths, it is also the most useful and durable. Against all forms of wear and tear silk stands longest. Taken by itself, a piece of plain silk is a pleasant thing, soft to the eye, grateful to the touch. To everyone who handles it genuine silk gives satisfaction. The

spinner sees the fine filaments grow into a straight, fine, lustrous thread; the weaver sees warp and weft lie softly down in close union, making a cloth surface, smooth, solid, flawless; silk imparts a glory to the dyer's colours, changing his blues into the brightness of the sunlit sky, or the liquid lustre of the sea, making the crimson throb with vital glow, and turning the browns into bronzes, the yellows into pure gold. To the warehouseman the fabric brings the sense of secure wealth, of a stock which does not deteriorate and always brings its price; the draper spreads it before the eyes of his customer with confidence, assured of its attractiveness and value. No material responds so fully to the artistic impulse in the fingers of dressmaker, milliner, seamstress, upholsterer, or housewife. Silk faithfully fabricated and nobly used brings calm joy.

But the silk industry and commerce has another tale to tell. If the fabric is the noblest, it can also be made the basest and most useless of all textiles. Tempted by the hope of acquiring wealth without labour, men have adulterated, doctored, and debased silk. In no branch of the textile industry has crime been so common. Loaded with corruptions, the fabric has rotted on the shelves of the warehouse and fallen to pieces on the bodies of the wearers. The weavers have spread thin wefts over weak warps and made cloths without strength or substance, besmirching the fair fame of silk. Time and again, during the past hundred years, the British public, despairing of obtaining genuine silk, have turned to other and less-pleasing cloths and threads; hoping once more, they have returned, and again have been sent empty away. The silk industry is the only branch of textile manufacture in this country which has absolutely declined. Other causes there have been, but in the main the silk industry has declined because it has not been honest and truly progressive. For methods adopted to lessen the cost of production we have nothing but praise; it is good that the beauty and softness of silk should refine and awaken the sense of beauty in as wide a circle of human beings as possible. The lowering of cost, however, should stop short of baseness, and a rotten fabric is dear at any price.

Silk Manufacture.—Textile origins are difficult to fix, but that China was the original home of the silk industry seems almost certain. Perhaps from the buried cities of Asia we may learn of an origin yet more remote, and the Chinese may turn out to have been no more than the repositories of the secret; but that they were the sole custodians of silk manufacture we have indubitable proof. According to Chinese

tradition, the invention of silk was owing to the genius of Empress See-ling-chi, wife of Emperor Huang-ti, who lived about 2700 B.C. Remembering the Oriental way of ascribing every event or achievement to the reigning monarch, we infer that the invention of the silk loom and the weaving of silk rose into national importance at the time. Carried on unheeded by mere artisans for at least three hundred years before, it appears that the silk industry came under imperial patronage then. The Empress See-ling-chi was constituted divine patroness of the silk-weaving craft, and to this day the Chinese weavers of Foo-chow prostrate themselves before altars erected in her honour. Imperial patronage may have been of some benefit to the industry; upon that point we have no information; but the royal ægis certainly imposed very strict limitations upon the trade. The wearing of silks was confined to definite classes of the Chinese aristocracy, and the secrets of silk culture and manufacture were jealously preserved within the Celestial Empire for close on fifteen hundred years.

In time, however, the knowledge of silk spread to Korea, and thence to Japan, arriving in the latter country, it is said, about the year 700 B.C. Chroniclers ascribe to the spread of silk culture and manufacture a much slower rate than seems justified by facts. According to some, nearly a thousand years elapsed between the entrance of silk into Japan and its advent in India. But Aristotle informs us that silk was woven at Cos before his day. He says: "Pamphyle, daughter of Plates, is reported to have first woven it at Cos". As Aristotle was born in 384 B.C., the silk industry must have existed in Europe much earlier than is generally supposed. In reality, silk has followed the ordinary channels of commercial intercourse, moving south to India, west across Bokhara, Khiva, Samarcand, Persia, into Asia Minor, thence to Greece, Sicily, Italy, Spain, and France, natural conditions forbidding the northward extension of sericulture, but permitting vigorous development of silk weaving in Holland and Great Britain.

The rise of great mercantile cities like Tyre and Sidon, with daring navigators and venturesome travelling merchants, the accidents of migration and conquest, like the invasion of India by Alexander or the conquest of Spain by the Moors, have acted as spring currents in the main stream of development, adding the stimulus of human passion to the force of economic tendency. Historians, busy with the wars of conquest and the feuds of savage chiefs, left industrial events unrecorded, and legends and conjecture filled up the blanks till the evolution of events brought clearer knowledge.

ORNAMENTAL COLOURED DRAPERY

(Warner & Sons, Newgate Street, London)

Of these legends Gibbon presents us with a fine specimen, taken from Procopius. According to the historian, in the year 551 A.D. two Persian monks of the Nestorian order came to Constantinople from China, where they had lived many years, and imparted to the Emperor Justinian the secret of the origin of silk and the craft of silk culture. They were encouraged by the emperor to return to China and procure some of the silkworm eggs for culture. He says: "They again entered China, deceived a jealous people by concealing the eggs of the silkworm in a hollow cane, and returned in triumph with the spoils of the East". There may be some foundation for the events so magnificently narrated, but we know that silkworm culture had been known in Persia centuries before, and that the long journey and simple stratagem were both foolish and unnecessary.

Silk Manufacture in Great Britain.—British industry owes much to those principles of religious toleration and political freedom which have found increasing expression in our laws and institutions. Up till 1549 the silk manufacture was practically unknown in the British Isles. For several years Philip II of Spain had endeavoured to reduce the Netherlands to the level of a Catholic province, requiring from the Dutch complete suppression of the Reformed Church. Failing to obtain obedience, he sought to bring the people to his feet by force of arms. Wearied of the long struggle, and desirous only of liberty to pursue their avocations peaceably, many Flemish weavers fled the country and sought refuge in Great Britain about 1563. In this way a small colony of silk weavers gathered in Spitalfields. The year following, some Flemings and Walloons, also silk weavers, asked and received the protection of the Duke of Norfolk, who settled them in Norwich in 1564. The sack of Antwerp in 1585 brought more refugees to this country, many of them weavers, and they formed small colonies in various towns and added to the population of Spitalfields. The Revocation of the Edict of Nantes by Louis XIV, on October 22, 1685, brought thousands of skilled silk workers to these shores from Lyons, Tours, and other great centres of the French silk industry. During the eighteenth century the British silk industry grew and flourished exceedingly, but when its Continental rivals recovered from the effects of war and persecution keen competition arose, which, instead of being met by added enterprise and improved machinery, was staved off by Government protection, grants, doles, and subsidies. The industry continued to decline, and when the last shred of Protection was removed by the French Treaty of 1860 it seemed as though its last gasp

had come. It is very remarkable, however, that silk throwing and weaving have slowly recovered during recent years, and still stand among the important branches of the textile industry.

The following are the chief centres of silk manufacture:—

Congleton.—Founded by a colony of French refugees in the seventeenth century, the principal part of Congleton silk manufacture was silk throwing. Coming thus into direct competition with the French silk-yarn manufacturers, Congleton was hit very hard by the final abandonment of Protection by the Government of this country. Up till 1858 silk throwing employed over 5000 people and forty mills. In 1890 the number of mills was six. Of late, however, the trade has recovered somewhat, producing yarns, ribbons, crapes, trimmings, bindings, and gauzes.

Coventry.—Silk ribbons have been the staple textile product of the Coventry people for 200 years. The fluctuations to which the trade has been constantly subject have now and again brought terrible sufferings upon the townspeople. Silk dyeing and weaving are the principal branches of the Coventry trade. By adopting modern methods and machinery the manufacturers have established the industry upon a sound basis. Most classes of silk goods are made in Coventry, comprising ribbons, plaids, failles, ottomans, neckties, and various trimmings.

Derby. — The silk industry of Derby has never been of very great importance, but it is worthy of special mention as the place where the first silk-throwing mill was established. Up till 1718 the silk weavers of this country derived their yarns wholly from Italian throwers. In that year, however, a Derby man named John Lombe brought over from Italy drawings of throwing machinery obtained while working in a silk factory, and set up a throwing mill in his native town. A fresh impulse was thus given to the British silk manufacture, and throwing mills were built at Congleton, Macclesfield, and elsewhere, rendering weavers independent of Continental throwers and lowering the cost of silk yarns. After a short period of prosperity the silk trade of Derby declined. Trimmings, surgical bandages, silk stockings, and yarns are the principal products of the mills remaining.

Glasgow.—At no time was the silk-weaving trade of Glasgow held to be of high importance, but the city has always been a centre from which manufacturers dispensed work to the handloom weavers in the districts round about. Silk cloths of elaborate design, fancy handkerchiefs, and other goods for the Eastern markets are still largely woven

by hand in the small towns of Renfrewshire, Ayrshire, and Lanarkshire. In addition, the power-loom weavers of Glasgow use large quantities of silk yarns in ornamenting light cotton fabrics.

Leek.—Shortly after the Revocation of the Edict of Nantes some French refugees came to Leek, and were kindly treated by the vicar. They settled and began silk manufacture, commencing with button making and extending to ribbons, brocades, handkerchiefs, and damasks. When these products declined in demand the Leek silk workers turned to fancy sewing silks, which are now the larger part of the output. Several large dyeing establishments prosper in the locality. Leek is one of the few English towns where the silk industry has not absolutely declined.

London.—The silk industry of London is centred at Spitalfields, where it began about 1560. During the long period of its existence the Spitalfields silk trade has changed from one kind of production to another several times. Beginning with silk stockings, the small manufacture was enlarged by the advent of the Flemish weavers, who had been accustomed to weaving brocades and rich garment goods. After a period of prosperity the trade in these cloths fell away, and plainer fabrics were woven. Though piece goods have never gone completely out of the hands of the Spitalfields weavers, they have been forced to seek employment in the manufacture of trimmings, chenilles, umbrella and sunshade coverings, scarfs and neckties, velvets for draping and upholstery purposes, and various wares. The velvet of the coronation robes of King Edward VII was woven at Spitalfields. The London silk manufacture has lately developed in the direction of employing hand-loom weavers on cloths of art design in surrounding villages. Several important firms have built up a considerable trade on these lines.

Macclesfield.—From the year 1756, when a silk-throwing mill was built at Macclesfield by Mr. Charles Roe, the townspeople prided themselves on being able to perform all the operations of silk manufacture, spinning the yarn and weaving it. Since 1859, however, the throwing trade has languished under the open competition of the low-paid workers of Italy. The weaving trade has not diminished to the same extent, and Macclesfield is still famous for its production of ladies' neckties, sarcenets, bandanas, and handkerchiefs.

Manchester District.—Silk was brought into close competition with cotton at Manchester in the early years of the nineteenth century, but the cheaper fibre soon drove it out. The higher fibre survived in

outlying districts, such as Patricroft, Leigh, Middleton, and West Houghton, where a number of factories and weavers are employed on piece goods, galloons, and smallwares. Here and there throughout Lancashire silk mills are at work. At Lancaster, the county town, Stockport, Preston, and Rochdale the manufacture of various classes of yarns and goods is carried on.

Norwich.—Silk manufacture began in Norwich in 1564, when the Duke of Norfolk obtained from Queen Elizabeth a licence permitting Dutch and Walloon refugees under his protection to settle and pursue the trade of silk weaving there. The weaving of crapes employs most of the looms. After a method of utilizing wild and waste silks had been devised by Lister and others, Norwich silk workers seized on it as a means of sustaining their industry. The spun silk is made into decorative furniture cloths and other heavy fabrics.

Yorkshire.—The silk factories of Leeds, Bradford, Halifax, and other towns in Yorkshire are chiefly engaged in the manufacture of spun silk. Manningham, near Bradford, is the place where Samuel Cunliffe Lister, afterwards Lord Masham, brought the process of silk-waste manufacture to a high pitch of perfection. Plush goods and velvets are the leading lines of production, though silk sewing threads and various fancy wares are also made. To the spun-silk industry of Yorkshire is owing the introduction of silk yarns into worsted cloths for men's wear.

From the revival of trade which took place in the early years of the twentieth century the British silk manufacture received a strong and salutary impetus. The increasing wealth of the nation, the growth of luxury, the raising of the standard of living among the middle classes, and the advance in artistic taste resulted in a larger consumption of silk than was ever known in this country. Technical colleges and schools of design, by improving the skill and taste of the operatives and designers, have greatly helped to restore, in some measure, the former prosperity of the British silk industry.

Thrown Silk.—Strictly defined, silk throwing is simply a series of reeling and doubling operations, for which we have no parallel in the manipulation of other textile fibres till the threads have been spun. In some cases the cocoons are imported and reeled; but, as a rule, the silks come to us in the form of reeled hanks. Raw silk cannot, therefore, come under consideration in our present section.

Waste Silks.—In what has been called the waste, or spun, silks the case is wholly different. Here the silk is taken as a mass of raw

fibres, to be prepared for the spinner. We recognize three different kinds of silk waste, each requiring separate preliminary treatment: 1, *floss, unreelable knubs, and broken cocoons*; 2, *wild silks*; 3, *factory waste*. After being prepared in their several ways, all these are brought into one form and shaped into the sliver for the spinner.

Knubs, Floss, and Broken Cocoons.—On the surface of the finest cocoons there is always a rough kind of silk called *floss*; the inner layers of the cocoon are so fine and so thickly covered with gum as to baffle the skill and patience of the reeler. Knubs and floss, therefore, are cast aside. Another fruitful source of waste in cultivated silks is the cocoons which are broken by the moths fully developed to carry on the race. Knubs and broken cocoons are practically of the same nature, and may be treated together; floss, though subjected to the same process, is generally put through by itself. Here it may be said that the variations in practice are very numerous, the methods adopted being dictated by factory conditions.

Preparation of Knubs, Floss, and Waste Cocoons.—A hot solution of soap is prepared in a dollying tub, fixed on a stand which turns it round on a tooth-and-ratchet arrangement, and equipped with a set of stampers. The broken cocoons and knubs are poured into the tub among the hot soapy liquid. When the drive is put on, the tub moves round one tooth at a time, and the stampers are lifted and let fall on the silk and liquid. Left to itself, the dollying tub soon has all the silk well under the soap and thoroughly soaked. The detergent liquid, aided by the elastic pressure of the dollies, drives out the gum and dirt. Care must be taken that the stampers do not bruise the fibres, and the operation should be quickly done, because the caustic soda in the soap has a deteriorating effect on the silk.

Another dollying tub, made so as to permit a continuous flow of water through it, is prepared, and the degummed cocoons and knubs plunged into the water. A screen at the outflow prevents the cocoons from floating out with the water, while the continuous turning of the tub keeps them from crowding in one place. If kept going a sufficiently long time, the water washes out all the soap and leaves the silk clean.

In drying the silk, heat should be avoided. The best method, where possible, is by centrifugal extractor. Fixed on a vertical spindle, a wire basket is enclosed within a circular iron tank, from which a waste pipe protrudes into a drain. Geared to run at any speed between 2000 and 4000 revolutions per minute, the basket develops an enormous

centrifugal force. The wet silk is placed within the basket and whirled round at high speed, the water running off into the tank below. When dry, the knubs and cocoons are taken out and made ready for further operations.

Wild Silks.—The largest addition made to the resources of the silk manufacturer was undoubtedly the discovery by Lord Masham of a method by which wild silks could be utilized. It was well known that many of the natives of India reeled and spun the cocoons of the wild silkworms infesting their jungles; but the patient labour the natives expended could not be imitated with commercial success in this country. For years experiments had been tried, chemists and others seeking to find a means of utilizing what was so evidently a valuable material. In 1857 Samuel Cunliffe Lister, a member of the firm of Lister & Co., worsted manufacturers, happened to meet a London chemist named Spensley, who had a large stock of wild silk for which he was unable to find a market. Mr. Spensley asked the manufacturer if he could not make some use of the material. Lister agreed to take a quantity at a halfpenny per pound for experiment, on condition of having the whole lot at a penny per pound if he succeeded in finding means of making something of the material. From all accounts it appears that no more unpromising textile material was ever experimented upon; it was a gummy mass, with hardly the vestige of its nature visible. Lister wisely concluded that his best plan was to lay bare the fibres, if possible, and then see what might be done with them. He boiled them in a strong solution of caustic soda and got rid of the gum, securing a mass of very tangled but indubitable fibres. In this condition the silk could be treated like any other textile fibre and formed into a sliver for the spinner; but Lister was not satisfied with having discovered the simple secret. His aim was to produce a thread equal in all respects to thrown silk, and so cheaply as to be able to compete successfully with that fine material in the open markets of the world. After an expenditure of £130,000, the great manufacturer attained such a measure of his aim that he was able to engage successfully in the manufacture of silks of the highest quality. The process, so far as it is preparatory, is the common property of the whole silk industry, and numerous variations have been wrought upon it.

Boiling Wild Silks.—As we have hinted, the treatment of wild silks in the raw state varies a good deal. Some manufacturers keep to the old method of boiling with soap to free the fibres from gum. In circulating boilers, by which the hot detergent is kept continually

circulating through the mass, the gummy fibres are made bright, free, and lustrous. Of course the heat of the boiling and the time given must be carefully measured, or injury to the fibres will ensue. This is one of the objections to the boiling process. Another objection is that the boiling process, if kept within safe limits, does not clear off all the gum. Consequently other methods have been tried and adopted.

Alkaline Treatment.—It is well understood that strong alkalis are solvents of silk; but dilute alkalis, carefully used, take away the gum without injury to the fibres. Therefore, as a preliminary to boiling in a soapy solution, the wild silks are immersed in a dilute alkali, washed clean, and then boiled as above.

Retting.—It is a curious fact that one of the very oldest processes of fibre treatment, namely retting, has come largely into use under the sanction of modern chemistry. Having seen that the action of fermentation destroyed the gummy matter in flax and hemp, chemists have enquired further and learned the principles upon which the action is based. Fermentation uncontrolled would soon dissolve all the silk fibres as well as the gummy matters; but it happens that the gum is more easily dissolved than the fibres, and therefore, by timing the action, the manufacturer can accomplish his purpose of dissolving the gum without touching the fibres.

The retting tanks are shallow vats, with steam pipes coiled on the bottoms. The gummy silk fibres are immersed in a soapy solution sufficient to cover them in the tanks. By steam introduced through the coils of piping the tanks are heated up to 170° F., and the mixture allowed to ferment. When the fermentation has gone far enough, the time being determined by the relative hardness of the gum, the steam is shut off, and the silk taken out and plunged at once into a dollying tub containing warm soap and water. Swift action is imperative in this case, because if the limy substance bred in the ferment is allowed to harden, the silk will be in a worse state than before, the substance being quite insoluble and only to be got rid of with the greatest difficulty. Washed thoroughly through the dollying tub and then rinsed in water, the silk is dried in the usual way. This process is very effective, but it demands special care and skill.

Factory Waste.—The waste which comes from the ordinary processes of manufacture is very easily made fit for spinning. It is good silk, already sufficiently prepared, but tangled and broken and unfit to become thrown thread. As a practical fact, manufacturers did not

wait for any inventor to teach them how to make use of that material. About the middle of the nineteenth century, when spinning machinery had been brought into efficiency, factory silk waste was treated like any short fibre. Cotton manufacturers reduced it to size for working on the cotton machines, and worsted manufacturers treated it like a long wool, after breaking it to uniform size. The yarns thus obtained left something to be desired, but it was silk yarn and very serviceable in many ways.

Opening.—Knubs, broken cocoons, wild silks, and factory waste all alike require to be opened out before being further operated upon. Factory waste silk was very simply treated in the days before patent systems were devised. It was run through the *rag tearer*, or *devil* (fig. 23), and reduced to small shreds of fibre, capable of passing through the common carding engine. At present, however, gentler means are adopted to achieve the purpose, with improved results. The willow opener is now employed both for wild silks and silk wastes of various kinds.

For breaking down the broken cocoons and knubs an ingenious adaptation of the oldest form of willow or beater has been invented. Over a revolving tray an endless band with a succession of heavy leather straps is geared, the band as it runs over the tray bringing the belt upon it with a whipping action. Laid on the tray, the knubs and cocoons are beaten upon by the belts and all the threads flattened out and loosened. If the operations described have been properly performed, the silk should now be a soft mass of fine threads. The rag tearer, willow opener, or beater brings the silk into the same condition as wool or cotton at the same stage of manufacture.

Silk Filling Engine.—When the wild silks come from the willow they are merely opened up and broken as little as possible, the willow being specially adjusted with that end in view. To lay the threads evenly together and reduce them to workable length, the filling engine (fig. 58) has been devised. This engine may be the same as that employed in ramie manufacture, but as a rule it is more complex and elaborate. On the front of the machine is the lattice feed, which may be a plain lattice or an endless broad band covered with little teeth. The upper part of the engine is composed of porcupine rollers, brushes, combs, drawing and delivery rollers, while at the back is the huge cylinder, with rows of spikes set at intervals of 4 or 5 in. The silk is carried up on the lattice into the grip of the first roller, thence through the successive working tools, which draw it out, pull straight,

comb, and brush, till it comes within the points of the spikes. These pull straight and form the silk into regular bands of straight fibres. When the cylinder is full the attendant cuts the silk into lengths equal to the spaces between the spikes, making the silk on the breadth of the cylinder into a bundle or strick.

For those silks which have been already reduced to short lengths the filling engine is both unnecessary and unsuitable. These may be formed into laps on the lapping machine, or sent direct on to the carding engines, according to the factory practice.

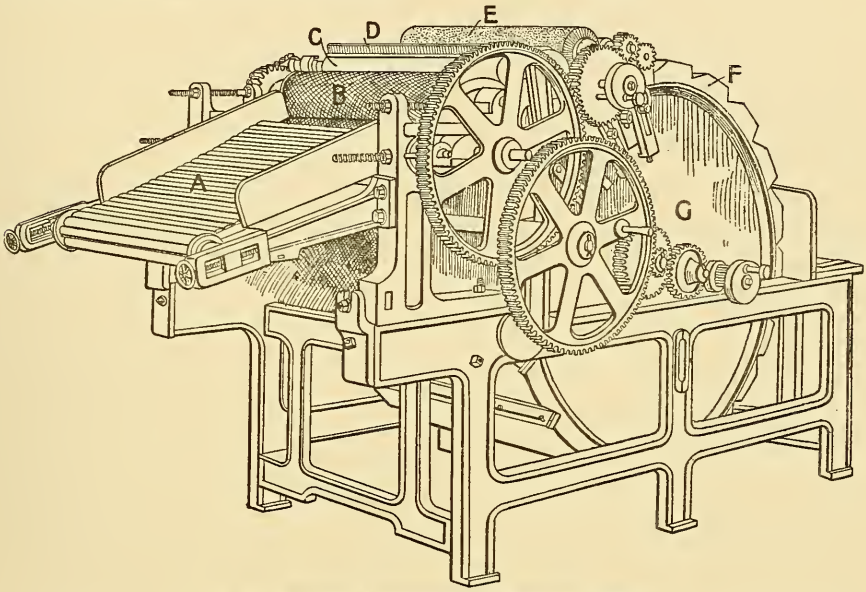


Fig. 58.—Waste-Silk Filling Engine (A. Robinson, Brighouse)

A, Feed lattice. B, Porcupine drawing-in rollers. C, Carrier roller. D, Comb. E, Wire-brush drawing roller. F, Spiked division of cylinder. G, Filling cylinder.

Dressing.—It is obvious that, by such methods as those described, silk filaments of all lengths are made. If the tangles drawn out by the filling engine had been all of one thread, the stricks would have been of one length, being equal parts of a continuous thread; but we know that the material is made up of threads of varying lengths, tangled in a disorderly manner, and therefore ending irregularly. This irregularity is reproduced on the filling engine, so that one filament may be continuous in two stricks or flakes, and end in the middle of the third, or, it may be, as a mere tip. We expect the greater number of threads to extend the full length of the flakes, and endeavour to take out all those which are short. To attain this object several machines

and sets of machines have been devised. Keeping out of view the system arranged by Lister, which is unique and continuously automatic from start to finish, and therefore beyond the scope of this section, we find two kinds of dressing machines, both of which answer the purpose very well.

Dressing Machine.—In a previous chapter we showed this dressing machine at work on ramie. The broad endless band, with combs fixed at short intervals across its outer surface, running round two rollers at opposite ends of the machine, and along over the bed, causes the combs to drag at the silk held in the clamps bolted on to the surface

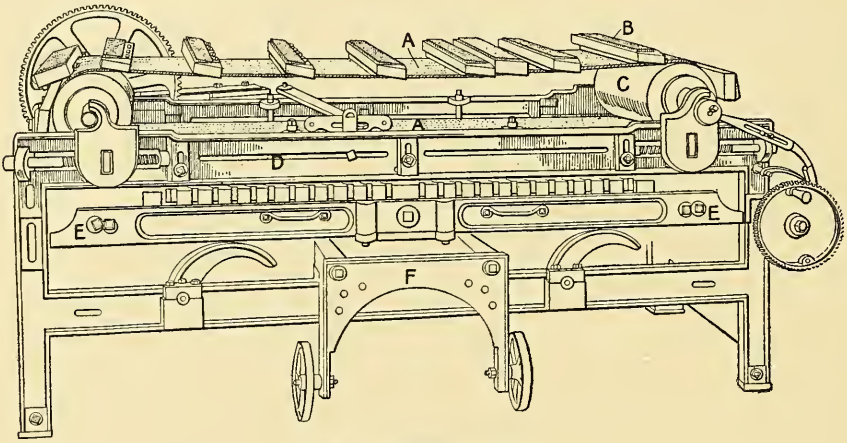


Fig. 59.—Dressing Machine

A, Endless combing band. B, Combs. C, Roller carrying the combs round. D, Front rail. E, Movable bed. F, Carriage of bed.

of the bed. All the silk filaments held merely by contact, or having a short grip in the "books", are drawn out and carried off by the combs. The combs are cleaned, the stricks are reversed in the "books", and the operation repeated. Those fibres which remain from the first combing are termed *first drafts*, and esteemed the highest quality. The silk taken from the combs is fixed into the books and also combed, the result being what are called *second drafts*, the fibres being equally regular but shorter. A *third draft* is taken, and the remnant is generally considered a kind of noil, to be put through the carding machines by itself. The higher qualities are ready for the combing machines, which are to convert them into the smooth sliver.

Three-cylinder Dressing Machine.—Because of its special form, and its suitability for small establishments, the three-cylinder dressing

machine is worthy of note. A large cylinder is placed between two smaller cylinders. Across the surface of the centre drum there are movable wooden rods. Upon these rods the stricks, or small bunches of silk, are wound, one end flying loose, whilst the other is firmly held. The surfaces of the two side cylinders are clad with combing teeth, set in the direction of the circumferences of both. The outer drums revolve in opposite directions, and upwards against the downward revolution of the centre cylinder. The ends of the stricks fastened on the central drum are constantly dragged against the teeth of the outer drums, and all the short threads pulled away. When one end of the stricks has been sufficiently combed, the silk is turned on the rod and the other end combed in the same way. Because of its great size, the central cylinder can move slowly and yet attain all the surface speed necessary. This enables the operative to change the stricks while the machine is running. The fibres drawn out by the combing are gathered and made into stricks for dressing into inferior qualities.

Silk Waste Factory Methods.—The separate machines described may be worked on any system, and specially in factories where spun silk is only a branch of a larger business. Factories wholly devoted to the production of spun silks are closely organized, and the operations brought as near to automatism as possible. In such a factory the material, after being freed from gum, is passed through the willow and formed into a lap on the combined opener and lap machine. The laps pass from the lap roller on to a table with a rocking filling head, above the edge of which is a strong knife automatically controlled. A long comb with spiky teeth moves parallel to the table, and as the rocking filler holding the fibres in its grip leans forward, it throws a portion of the silk over the spikes of the comb. The filler rocks backward and pulls taut the fibres held in the comb. At the same moment the knife comes down and severs the taut silk. Bearing off its spoil, the comb passes onward, receiving a lot of fibres from three other rocking fillers. At the end of its traverse the comb drops down to a lower level; but as it drops, two sets of nippers from above and below come and snatch up the silk. The nips turn over and deposit the silk on an endless band, which, again, acts as feed to the sliver-forming machine. Already another set of combs is coming forward bearing silk, and it takes the place of the comb which has gone under, to be in turn dispossessed of its spoil of fibres. By the double drag of the rocking filler and comb, in the first instance, and the comb and the nips in the second, the silk is straightened and drawn out.

Combined Machines.—A combination of the latter method with the use of the filling engine and dressing machine is described in a report in the *Journal of the Society of Arts* as follows:—

"The type of the mechanism is that used in the cotton or wool manufacture, for when silk ceases to be a filament it becomes a fibrous material like cotton, and may be treated as such, subject to the consideration that the staple or length of each fibre is greater and more varied than that of cotton. The entangled fibres of the silk are reduced to lengths of about 8 in., and to 'flakes' measuring about 8 in. by 3 in. These flakes have been produced by a process of partial tearing, cutting, and careful combing, which lays the fibres parallel and enables an attendant to reduce them to suitable lengths. These are placed in baskets and taken to a machine called a spreader. They are then laid by hand, one at a time, upon an endless band, by which they are advanced until brought within the influence of a brass (porcupine) roller, with fine teeth upon its surface. This roller delivers the fibres to a series of fine-toothed metal combs which are moving parallel to their length, and carrying with them the silk. By the action of these combs, and fluted rollers which receive the silk from the combs, the 'flakes' are not only further combed, but owing to the speed of the rollers being greater than that of the combs, the silken fibres are drawn forward elongated, the ends of one flake being, as it were, fitted over the ends of another, and 1 yd. of these flakes is extended to from 10 to 30 yd., according to the purpose for which the yarn will be required. The motion of the travelling combs is accomplished by the ends of the comb being carried on the grooves of two parallel square-threaded screws, and passed from one set of parallel screws to a lower set by 'striking' cams, which cause their descent at one end; and by a similar but reverse screw motion to the former, each comb is carried back, and rises to the first position. The combed and drawn silk fibres are conveyed by an endless band, in the form of a light flake-like ribbon, and coiled upon a large wooden wheel, from which an attendant takes off regular lengths and lays aside for the next process."

In an industry which offers prizes so large for efficiency as silk manufacture, the effort after improvement is unceasing. Later machines and processes do not, however, differ in principle from those described.

CHAPTER VI

Carding

Common Principles of Carding, Combing, Gilling, and Spreading.—The end of textile manufacture is the woven fabric. Before a fibre can be made part of a thread fit to be woven, it must be clean, straight, and ranged. Each fibre, be it cotton, wool, flax, hemp, jute, ramie, or waste silk, has an individuality; it may be clad with dirt, doubled, snarled, looped, bruised, or otherwise defective, and each one varies in degree of defect. The problem now is, what process should be adopted to rid the fibres of these defects. The worker cannot take up each little fibre, wipe, unfold, and disentangle it. In the opening, sorting, mixing, scutching, and lapping operations, to which the short fibres are subjected, they are treated in the mass. The long fibres, it is true, are hackled and dressed with a certain small measure of attention to the individual, but only in a very general way; for even there the object is to obtain masses of fibres in a given condition and of a certain known quality.

In all textile manufacture the stages of the successive processes are graded and gradual, one operation shading into another following; but some operations contain within them points of departure, and we miss the whole secret if we fail to note the moment of change. Carding, combing, gilling, and spreading are all operations which mark such points of departure in the industries in which they are employed. By these processes the fibres are individualized, each one separated from every other, and cleaned, straightened, and laid in a given direction. Even if the fibres are combined again, crossed, and intertwined, as in the woollen and felt slivers, the amalgamation is not heterogeneous but intelligently directed.

The common product of all these machines, therefore, is a sliver, a thick, soft rope, composed of fibres, cleaned, unravelled, and laid together in a definite order.

Primary Tools and Methods.—When the making of a piece of cloth was esteemed a high and wonderful art, the maker had no tools. With his fingers he selected and cleaned each fibre, delicately building up that marvellous thing, a thread. But cloth production demanded more and ever more threads, and the fibres could not be prepared quickly enough, till some inventive genius made a wooden hand with which to comb out and clean the fibres. From this invention

have come all the combing, hackling, gilling, and spreading machines in existence. Though the period in which that primitive tool was used lies far back in the dim unknown, its immediate derivatives are still extant. The roughing hand hackle of the hemp-rope spinner, the hand comb of the wool comber, the hand cards of the cotton spinner, just laid aside by generations not long passed away, bear distinct traces of the tool which was their common progenitor.

To some minds these reminiscences of primitive practices may seem rather far-fetched and needless; but our aim is wholly practical. The swiftly running, automatic machine obscures the steps of the process it operates. Not until we have seen the slow and detailed action of the hand worker, nor until we have clearly known the tools which have become automatic and power-driven in the great factory, can we grasp the inner principle of the manufacturing operations. More important still, we can never escape from the bondage of mechanical labour until we have caught the idea which was the motive of the founders of our industry.

Cards. — Long before cotton came to this country hand cards, combs, and hackles were used in preparing wool and flax for the spinners; but it was for cotton that mechanical cards were devised. From earliest times the cotton spinners of India carded their cottons by hand before spinning. Hand cards were of various shapes, but the most common of the older models were flat pieces of wood closely studded with little spikes and fitted with a handle. A pair of these was required for the operation. The fibres were drawn into the teeth of the card held in the left hand; with the card in his right hand the carder combed down, or carded, the material, working the cards face to face. By continued drawing and slackening, by changing hands, and adapting the length of the strokes to the state of the fibres, the carder cleaned and straightened the fibres and laid them evenly together.

Some improvements were made in the hand cards before the machinists began to transform them. Instead of the stiff iron spikes riveted in a board, a kind of wire-brush foundation was invented. Short lengths of fine iron wire, sharpened at both ends, were driven like staples through a square of pasteboard stiffened with linen, or a piece of leather, and bent over to present their points obliquely. The wire staples were inserted into the backing or card in rows, and when filled the card was nailed on to the board with the handle. Thus the carder possessed a tool holding a vast number of points securely fastened, and giving a firm and even grip on the fibres.

Next, one of the pair of cards was fixed on a stout stand, affording the carder greater power over his tool at less than half the labour.

Development of the Carding Engine.—To the cotton industry belongs the credit of having caused the development of the carding engine. In the year 1738 Lewis Paul, an ingenious and unfortunate mechanic, of Birmingham, invented the first carding machine. Though overshadowed by his great successor, Richard Arkwright, there is no doubt that Paul was the real inventor of the carding engine. "The cylinder cards, invented by Lewis Paul," says Dr. Andrew Ure, in *Cotton Manufacture of Great Britain*, "and patented in December, 1748, were covered parallelly to the axis with fillets of leather thus mounted, having intervening stripes free from points. A concave card of the same curvature as the cylinder was applied to its under surface. Hence, on turning the cylinder by the handle at its end, the two bristling surfaces worked against each other and performed the carding operation. When the filaments were thought to be sufficiently carded, the stationary concave part was let down, and the cylinder was then stripped of its wool by means of a comb made of a bar of wood bearing a row of needles." This was the origin of flat carding.

Lewis Paul failed in business at Nottingham, and his carding invention was bought by a hat manufacturer from Leominster, who applied it to the carding of wool for felt making. For several years the idea was tossed about like a seed grain on the wind, finding no soil on which to take root.

In May, 1748, Daniel Bourn, of Leominster, patented a machine in which four parallel rollers covered with card clothing were set close together, thus originating roller carding.

About 1760, James Hargreaves, inventor of the spinning jenny, apparently knowing nothing of Paul's cylinder cards, invented an apparatus of his own, by adapting the stock cards then used in the woollen trade. Fixing a pulley in the ceiling of the carding room, above the stock card, Hargreaves tied a rope on to the movable card, passed the cord through the pulley and weighted it at the end with a balancing weight. By this means the carder's hands were freed, and he was enabled to work a number of cards on the stocks, while performing the operation more rapidly. As a practical makeshift this contrivance of Hargreaves had merit, but it was not a real contribution to the development of the carding engine. Most probably there were contrivances equally ingenious in many of the

carding rooms of Yorkshire and Lancashire, devised by men of whom history has taken no notice. Hargreaves, however, was afforded another chance of adding to his reputation as an inventor by a cotton manufacturer named Peel, grandfather of the famous Sir Robert Peel, who brought to his notice Lewis Paul's invention, and gave him a commission to make it a practical machine. The inventor accepted Peel's offer, and built a cylindrical carding engine, consisting of three cylinders covered with card fillets. From this machine the cotton was doffed at first by women using hand cards, but afterwards Hargreaves added a doffing roller, carrying a set of tin plates which scraped the cotton off the cylinder. Though containing many valuable ideas, the machine was not a success.

In 1775 Richard Arkwright brought out a patent for a complete stationary flat carding engine.

During the period between Lewis Paul's publication of his patent and 1775, many inventors had been working at the carding machine. The last few years especially seem to have been crowded with effort. After all, however, the carding engine was a very inefficient tool. The feed was badly regulated, the sheets of card clothing gave a streaky appearance to the carded material, the cylinders working on the main cylinder were not properly related, and the doffing apparatus took off the fibres irregularly. There were other defects, even in the best models. With his comprehensive intellect Richard Arkwright conceived the engine as a whole. He established a definite relation between the feeding apparatus and the doffing cylinder, and invented the doffing comb; he devised a form of filleted card cloth which evenly distributed the fibres; he adjusted the parts working over the central cylinder to their functions. Whether he invented or adapted, Arkwright certainly made the carding engine an efficient machine. Later inventors have improved on his mechanical contrivances, but they have not gone beyond his conceptions; Arkwright is the Shakespeare of textile manufacture.

The Carding Engine.—Since Arkwright's day the carding engine has been improved in many details; it has been adapted to nearly all kinds of textile fibres and employed in most branches of the textile industry. The name of the machine has, therefore, a different significance to the workers on different textiles. To the cotton worker the carding engine employed on jute seems altogether strange, and to him the scribbler of the woollen manufacturer is quite needlessly complex. On the other hand, the carding flats now generally used

for fine cottons are barely intelligible to the woollen worker. Yet there is, after all, one carding engine, one mechanical principle, or set of principles, to which every kind of carder must conform.

Taking the general mechanical structure of the carding engine (fig. 60) first, we note that the main tool is a large cylinder placed in the middle of the machine. Over the cylinder, generally named the swift, in adjustable bearings, with driving pulleys on their necks, are hung rollers, alternately large and small, the former being called workers and the latter clearers. At the back of the machine, in close

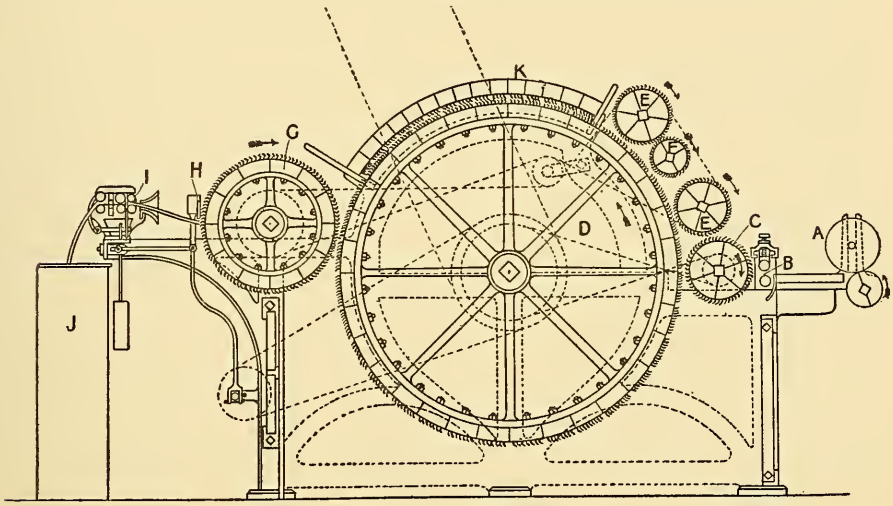


Fig. 60.—Old Form of Carding Engine

A, Feed lap roller. B, Fluted feed rollers. C, Licker-in. D, Main cylinder. E, E, Workers. F, Stripper. G, Doffer. H, Doffing knife. I, Sliver-forming apparatus. J, Sliver can. K, Carding flat.

touch with the swift, is a smaller cylinder named the doffer, over which stretches a steel comb. In front a feed lattice and set of feeding rollers are placed.

A very special feature of the carding engine is the mobility of its parts. The spaces between successive cards are wide or narrow according to the function of each and the length of staple of the fibre being carded, the bearings having adjustable screws. Every cylinder and roller, or each set of rollers having the same function, has its own driving gear, and the relative speeds of all the parts are fixed according to requirement. In the carding engine formerly used in the cotton trade the ratios of speed per minute were as follows: Swift, or main cylinder, 1600 ft.; feed, 1 ft.; dirt roller, 15 ft.; workers, 40 ft.; clearers, 400 ft.; doffer, 70 ft. Whilst the structure of the machine imposed

certain obvious limits on variation, the ratios could be altered considerably to suit the kind of fibres and the classes of work.

Card Clothing.—The structure of card clothing is easily understood from examination of the hand cards; but when the cloth is put round a cylinder or a roller, some modification is necessary. Let us take a simple example from the start. Leather was until recently considered the best foundation for card cloth; but it is a costly material, and cheaper foundations were sought. Besides, leather lacks uniformity, and is difficult to stretch evenly upon the cylinder. One of the best substitutes is several plies of stiffened linen, cotton, or other fabrics, made elastic by a layer of indiarubber in between. Since rubber has gone up in price so much, the cheapness has become doubtful, but the advantage has become apparent. Card clothing

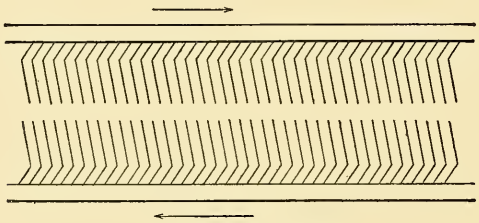


Fig. 61.—Card Clothing

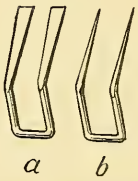


Fig. 62.—Card Dent or Staple

a, Before grinding. *b*, After grinding.

may be made up in sheets, or in strips 1½ in. and 2 in. broad, the sheet being now the most common form. The foundation cloth, made flat and even, is carefully pierced, the spaces between the holes proportioned to the number of card points per inch. As we shall see hereafter, the closeness of the points in card clothing varies greatly, ranging from 400 upwards per square inch. The wire, sharpened at both ends, is bent into three sides of a rectangle, two sides and a base, the base being exactly the size of the space between all the points in the card-clothing. Next, the two points are bent to an angle, resembling a flat hook, so that the points of the wires shall be parallel with the surface of the cylinder when the cloth is laid on. It must be said, however, that the angle of the wires varies in different rollers and on different engines, the particulars of which shall be specified in the proper place. One by one the wires are inserted, and the strip or sheet of card clothing made.

If we put a tuft of fibres between two of those card cloths and draw them evenly in contrary directions, the teeth will pull the fibres

apart in fine lines. On the other hand, if we let the one card strip hold all the fibres, and make the other follow after it at greater speed, with the points of the wires in the same direction, the second will unhook all the fibres from the teeth of the first. These two simple facts lie at the basis of all carding.

Clothing the Cylinders. — Some carders prefer to use sheets of card clothing for the main cylinder, while covering the smaller rollers with fillets spirally laid. Cotton carders use sheets long enough and broad enough to entirely encircle a whole cylinder. Woollen workers,

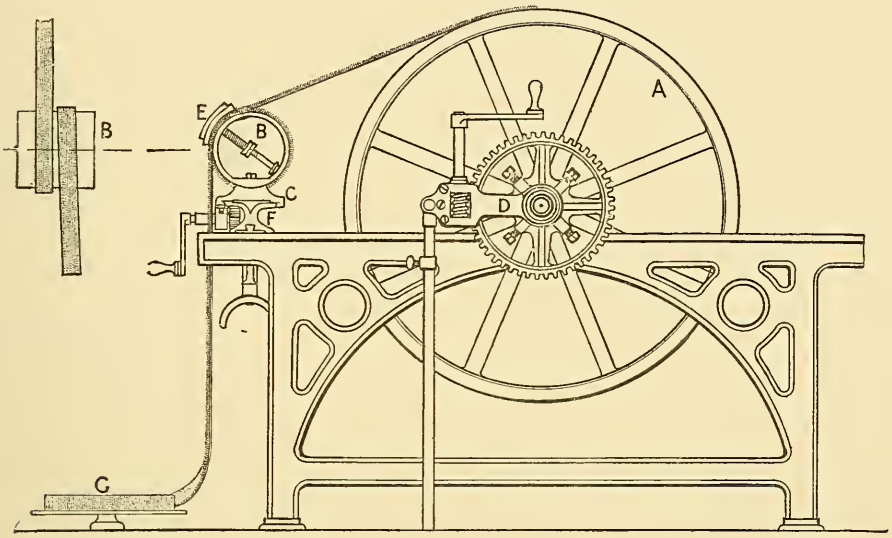


Fig. 63.—Card-Clothing Appliances

A, Cylinder of carding machine. B, Tension drum. C, Carriage travelling on the rail F. D, Worm wheel screwed to axle of cylinder. E, Back plate. G, Coil of card.

however, whose interest in the matter must be kept before us, have smaller sheets, 4 in. or 6 in. wide, cut to the breadth of the cylinder and carefully laid on. Being a skilled handicraft, card clothing is not done by rule, but according to the methods deemed best by each workman. A common practice is to make a pencil line round each end of the cylinder at the point where the clothing ends, and then to mark cross lines the size of the breadth of the sheets. From these cross marks draw straight lines from side to side, thus indicating the exact position of every sheet. Having fixed the cylinder firmly in position, lay a sheet along the marked line, tack it down on the cylinder, and stretch evenly. If the marking has been accurately done, the edge of the sheet should fall exactly on the line below. Tack this side of

the sheet down, and lay the next sheet in place. By this method the whole cylinder can be accurately clothed.

Card clothing with fillets is now more general in the woollen trade, and the results justify the preference. If properly adjusted, the strips lie closely and evenly together. The cylinder to be clothed is placed in the frame so as to be readily and regularly driven. Another roller or cylinder is set parallel, to act as a stretcher for the filleting and keep it at even tension. Laid at the proper angle, the filleting is wound on the cylinder, care being taken to avoid overlapping and openings between the layers of strip.

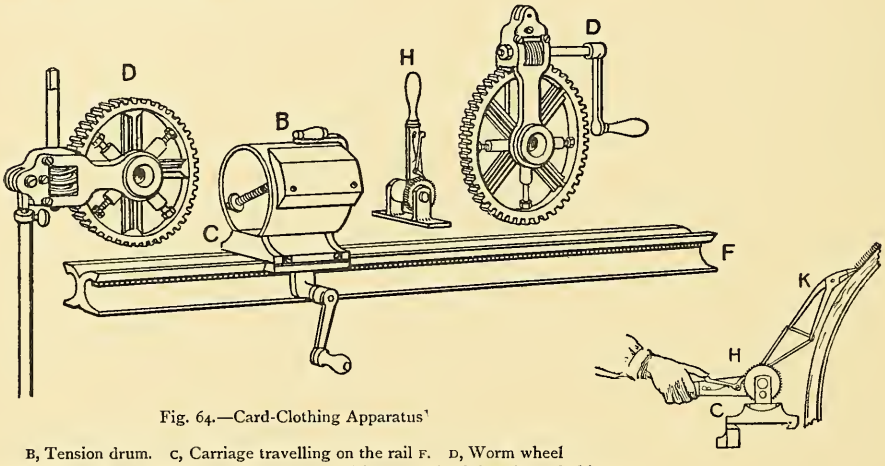


Fig. 64.—Card-Clothing Apparatus

B, Tension drum. C, Carriage travelling on the rail F. D, Worm wheel screwed to axle of cylinder. H, Ratchet. K, Pliers used for fixing sheet clothing.

Mechanical Aids to the Clothier.—Card clothing by hand demands strength and skill. As a means of lessening the call upon the human agent a set of tools have been invented. Upon the end of the shaft of the cylinder a worm wheel, with handle and leg rest, is fixed, enabling the worker to retain full control over the turning of the cylinder. At the back of the cylinder, and the full width of the frame, a strong slide is placed, and on it a small drum, having a back board lined with emery and a moving screw, is geared. The strip of card clothing is wound twice round the drum, within the back board, the emery of which gives a sharpening touch in passing. From the drum the filleting is led up round the cylinder and tacked on at the proper angle. By turning the handle of the worm wheel on the shaft, the workman pulls the card clothing round the cylinder, while the drum holds it tense. As the drum gives off the strip, it moves along the slide, carrying the filleting from end to end of the

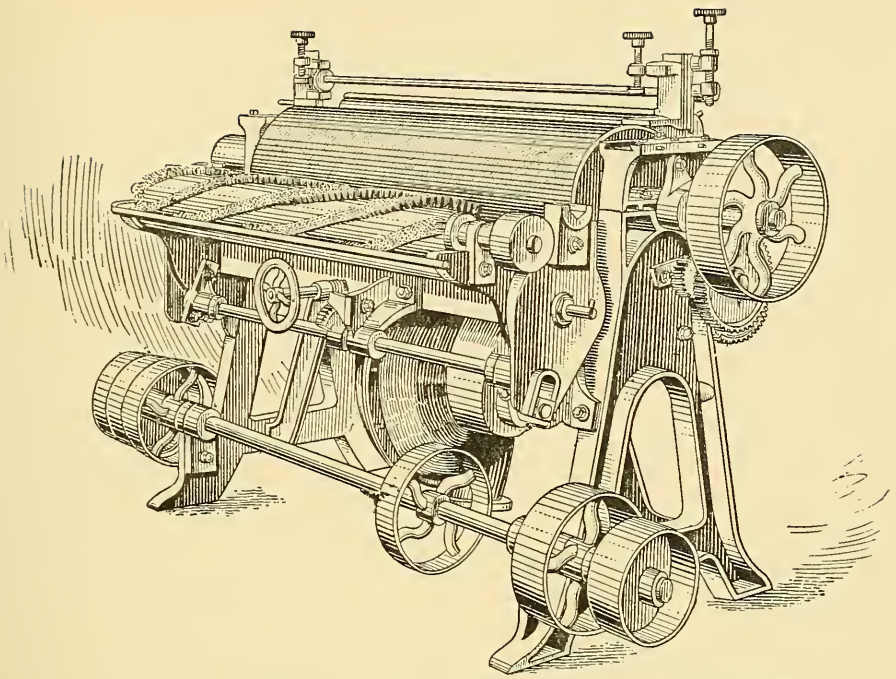


Fig. 65.—Grinding Frame for one Flat and one Roller, with Dust Fan and Revolving Brush (Dronsfield Bros., Ltd., Oldham)

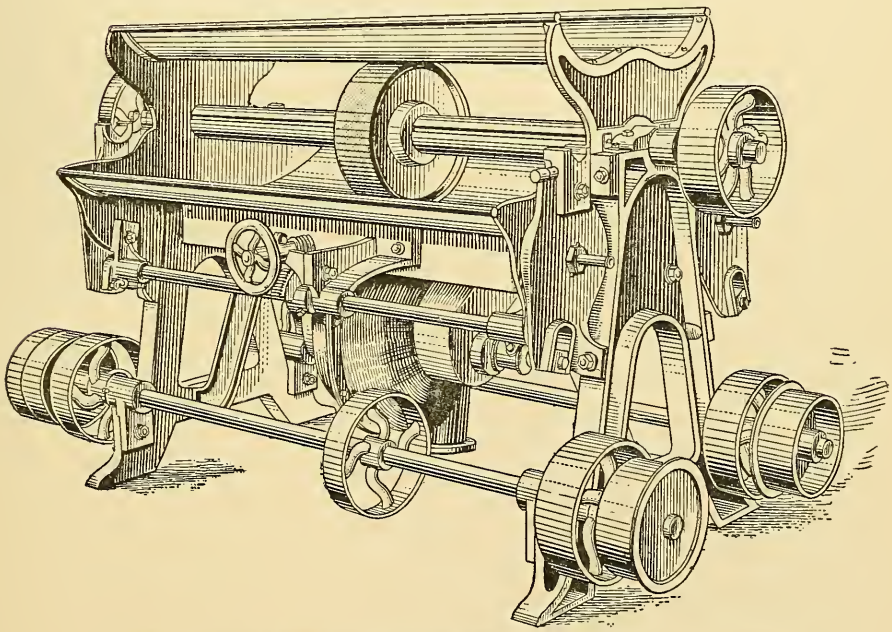


Fig. 66.—Grinding Frame with Traversing Emery Wheel, for two Rollers or Clearers (Dronsfield Bros., Ltd., Oldham)

cylinder. By that apparatus much labour is saved, and all risk of overlapping and inaccurate laying avoided.

Card Grinding.—The points of the wires in card clothing must always be kept sharp; but before sharpening can commence the points have to be made even. Irregularity in the teeth of a carding cylinder or roller effects much mischief. Facing is the technical term denoting the act of reducing all the points to one level. When the sharpening is done by hand, facing is merely part of the whole job; but if the grinding machines are employed, the facing is done first as a preliminary operation. But the action and the tools are the same, and we shall, therefore, take the more important operations first.

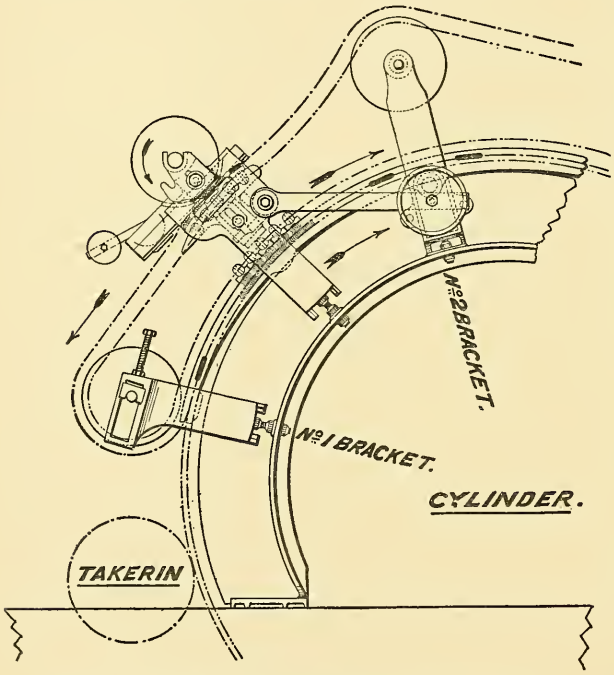


Fig. 67.—Card-Sharpening Attachment to Carding Engine (Front)

The needle-shaped point is the ideal one for card-clothing wires. On new carding engines we generally find the needle point; but on old cards the chisel point is more common. The reason for this is not difficult to find. To make a needle point it is necessary to get all round the wire; but the problem is how to get round wires crowded at the rate of from 400 to 600 per square inch. If hand sharpening were cheap, reliable, and expeditious, there would be no problem, for human ingenuity has not failed to devise a tool which enables a man to accomplish the task. But the work of the hand sharpener is costly; on the main cylinder alone he has to sharpen, on the average, over 2,000,000 points. This takes time, and the time of skilled craftsmen is costly. If, by using card clothing with chisel points, we can lessen the cost without very materially lowering the quality of the product, there seems little reason for stickling for the needle points.

The tool of the hand sharpener is a flexible straightedge, covered with emery, and named the *strickle.* Armed with this tool a skilful workman can make card clothing of the very highest quality, regular, straight, and needle-pointed.

Wire teeth rapidly blunt under the strain put upon them by the work of carding, and three methods have been contrived for mechanically sharpening the points. Two are independent machines, and the third is a set of grinding tools on the carding engine itself.

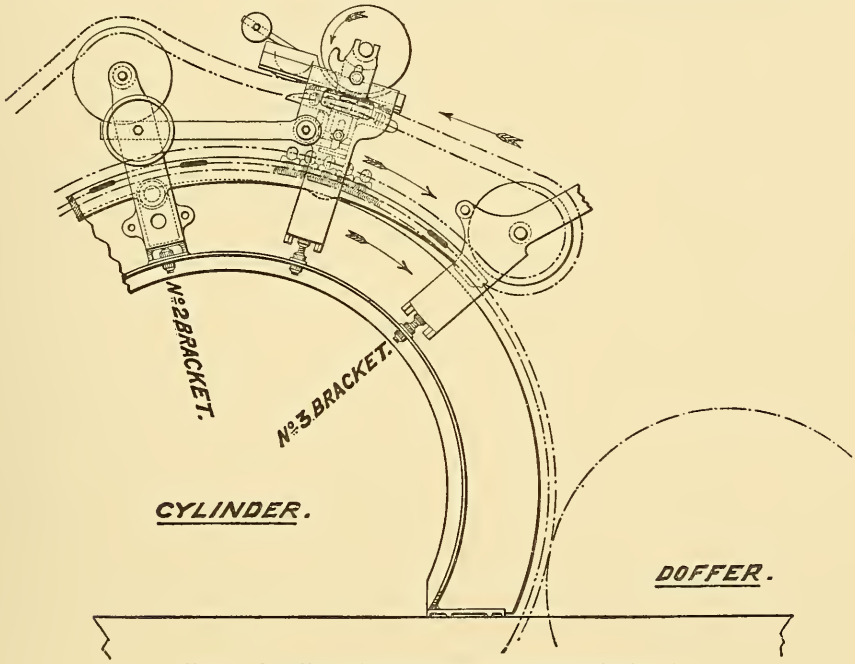


Fig. 68.—Card-Sharpening Attachment to Carding Engine (Back)

The *roller grinder* is composed of an emery roller, rather longer than a carding cylinder, and graduated supporting brackets on which the roller or cylinder to be ground can be securely and evenly fixed. The machine does the work expeditiously and with unvarying accuracy. Laid on the supporting brackets, the cylinder is brought into contact with the revolving emery roller, which quickly imparts to the wire clothing sharp chisel points. It is objected that the roller flattens too broadly the points of the wires. To remove the objection, the emery on the roller is made of a coarse grain, so that the hard emery works on the sides of the wires. Card clothing produced by this method, however, is frankly chisel-pointed and can hardly be anything else.

Another machine is the *disc grinder.* In shape the disc grinding machine closely resembles the roller grinder; but, instead of a roller, we have a round disc of emery which travels from one end of the cylinder to the other on a spiral shaft. Some advantages are claimed for this machine. The disc is certainly easier to handle than the roller in every way; but the relative merits of the machines do not concern us here. The ideal grinder is yet to be invented.

Card grinding rollers are frequently fixed on the carding engine itself (figs. 67 and 68). These appliances help to keep the cards in condition, but do not altogether obviate the need for special grinding.

It is a common practice among users of edged tools to grind down the edge to be sharpened to a level, and the practice is also often necessary in the sharpening of card clothing. Facing, as the operation is termed, is perhaps the one process which can be best carried through by the roller grinder. When grinding for points, we make the cylinder or roller revolve against the grinding tool in the direction of the bend of the wires. By working the opposite way we bring the points of the card clothing directly against the emery of the roller. Care is demanded in this operation. The pressure of the emery roller should be very light, or the wires will be bent out of the true, and much damage done.

Card Setting. — Carding engines are very heavy machines and produce strong vibrations. Every part is delicately adjusted to every other, and the slightest disturbance of the balance reduces the efficiency of the machine, if it does not actually bring on injury. A carding engine, therefore, requires a solid foundation; it is commonly placed on the ground floor of the factory, and may even need a concrete foundation in many cases. At the very least the carding engines require a strong, level floor, and isolation from the influence of other machines. Having made sure that the frame stands perfectly level, the erector proceeds to put in the cylinders and rollers.

Before setting the cards, we have to take into account the kind of fibre which is to be carded. If the fibre is short and fine, the rollers must be set close to the cylinder, or some portions will be missed altogether; if a long fibre, the cards require to be set apart, or broken and doubled filaments will result. The general principle that the length of the fibre determines the relative positions of the cards can here be laid down, but the practical working out of the principle belongs to each special branch of the textile industry.

As we have pointed out, the carding engine is a mobile tool, every

part being variable within necessary limits. Mobility has its dangers as well as its advantages. To make every roller and cylinder perfectly level with the adjustable screws is not so easy as laying them in solid bearings; but the slightest obliquity of any part of the machine is attended with serious consequences. By careful measurements, by observation with eye and ear, the desired end can be achieved. A few revolutions of the machine show whether or not all the wires lie in place, the sharp vibration of the offending point betraying it; but the efficiency of the whole engine cannot be ascertained till the lap has been put in and work has begun.

These principles of carding construction are common to all branches of textile manufacture. Cotton carding has aims different in many respects from wool carding, and jute carding differs widely from both; but the principles stated are common to all. Having mastered the rudiments of carding in general, the student is equipped for understanding easily the operation as applied to his own special branch of textile manufacture.

Cotton Carding.—The cotton has been formed on the scutcher into a sheet wound on a roller; it is of known weight, say 1 lb. per yard. In the main the object of carding is to convert the lap, as we name the sheet, into the thick, soft rope or sliver which is the beginning of yarn; but carding also serves other purposes. Despite previous preparatory labours our cotton is still too dirty for the spinner's use; the fibres lie crossed in all directions, knotted, doubled, and twisted. Three objects are therefore aimed at in carding cotton: 1, the cleansing of the fibres and rejection of short and broken cotton; 2, bringing the fibres into parallel order, so that they all lie in one direction; 3, the conversion of the thick lap into a given length and weight of sliver. To accomplish these ends a variety of methods are employed. A single passage through one carding engine was seldom regarded as sufficient for the purpose up till very recently. In mills of the older type, two carders are sometimes employed, the first being called the *breaker card*, the second the *finisher card*, the latter having the finer teeth and quicker motion; but these machines are now only introduced for low-grade and waste cottons. Some manufacturers remake the lap on the breaker card, but others let the carded cotton pass through the sliver-forming apparatus and bring back into the lap form with the derby doubler for the finisher card. The latter is the better practice; but as it involves the employment of an additional set of machines, the relation between the value of the cotton

and the cost of manufacture has to be considered. In coarse-spinning districts double-carding engines are frequently employed.

The ideal carding engine has not yet been built, or, if it has been, the majority of cotton manufacturers do not know it. In consequence the variety of carding engines at present working is very considerable. Machinists and inventors are constantly devising improvements, though without materially changing the form of the three principal types of machines, namely, the *roller*, the *Wellman*, and the *revolving flat carding engines*. It is evidence of the great genius of the early inventors of textile machinery that all the principles embodied in the newest carding engines were laid down in the fifty years between 1730 and 1780.

Roller Carding Engine.—In general structure the roller carding engine of the cotton trade is the typical carder. From it all the other machines have been derived; but improvements have been introduced which made it specially a cotton carder. To examine this machine thoroughly we shall begin at the fore end and work to the back, taking each part in succession.

The lap of cotton is brought into contact with a plain roller, revolving at the rate of 9 in. per minute, which turns the lap and draws it forward under a fluted feed roller, formed to grip the lap firmly while pushing it onwards. Feed roller and lap roller are driven at the same speed, and there is no drag between them; but the former must take a good grip on the lap because of the action of the next roller. This is the licker-in, the first of the card-clothed rollers, but covered with points of a peculiar shape. Maintaining a speed of 800 ft. per minute, and turning forward upon the feed, the licker-in gives the cotton a sharp pull downward, combs portions from the fringe of the lap, and carries them to the cylinder running behind it.

Licker-in.—The teeth of the licker-in are long, flat, and ground to a point on the slant, like double-edged knives, and slightly inclined in the direction of the revolution of the roller. Devoid of hooking capacity, the roller literally licks in the fibres to the cylinder. As the latter travels at twice the rate in surface speed, and the teeth of both are inclined the same way, it naturally follows that the licker-in is always completely denuded of the material it has taken from the feed roller.

A point to be noted here is the successive accelerations of speed in the three agents. The licker-in has a surface speed 900 times greater

than the feed roller, and the surface speed of the cylinder is double that of the licker-in. This means that the lap has been broken up by the licker-in, no substance being able to stand attenuation so swift. Solid impurities drop away from the cotton; the fibres are straightened to meet the force of the draft, while the teeth of cylinder and licker-in searchingly divide them. In addition to acting as a comb on the fibres, the teeth of the licker-in perform the service of beaters, driving out the hard subtances which have escaped the scutchers, and for that reason are made strong and of a blade shape.

Dirt Roller.—Just above the licker-in sits what we call the dirt roller. It is formally one of the set of workers, and often is so placed as to be undistinguished from the rest; but in many carding engines this roller is specialized. The latter arrangement is the better. The roller is driven at the slow rate of 15 ft. per minute, in the same direction as the main cylinder, but with teeth reversed. Various methods of clearing this roller are adopted, the latest being the *mote knife*, or a vibrating comb. For it is necessary to provide some means of assisting the dirt roller in cleansing the fibres which it takes from the cylinder, the whole purpose of it being to take away the little bits of leaves and other pulverized matters which have remained in the cotton.

Workers and Clearers.—Above the dirt roller, and inclined towards the circumference of the main cylinder, are the pairs of rollers named workers and clearers. The worker is the larger roller of each pair and runs in the same direction as the main cylinder at the rate of 20 ft. per minute, with teeth bent in reverse direction from its revolution. It is worth while explaining the peculiar character of the worker. The function of this roller is to card out all the loose and tangled fibres on the cylinder and to cleanse them. It would be easy to put the worker in direct opposition to the main cylinder; but if that were done, two things would happen. The fibres would be ground to powder between the two opposed forces, and the clearer would be rendered useless. By giving the teeth of the worker a retreating motion towards the teeth of the cylinder, the blow of contact is mollified. Revolving slowly, the worker also condenses the cotton already severely attenuated by the interaction of the foregoing roller and the cylinder. On the impulse of a desire to lessen the severity of the carding motion, one would be tempted to suggest a quickening of the revolutions of the worker; but second thoughts show that one important part of the worker's duty would thereby be lost.

Now let us examine the clearer roller. The speed of its revolution is 400 ft. per minute; it runs in the same direction as the worker, but the teeth of the clearer are turned in the direction of its revolution; therefore it follows up the teeth of the worker and takes the fibre from it. On the other side the teeth of the clearer are in the same direction as the teeth of the main cylinder; but the speed of the surface of the cylinder is four times as quick, and so the teeth of the latter pick the fibre away from the teeth of the clearer in the gentlest manner possible.

The worker gives the crossed and entangled fibres a new starting point, so to say; the clearer, acting as the intermediary between the worker and the main cylinder, begins the work of drawing out the fibres again, by its superior speed attenuating the flow of cotton by twenty times, and softly yielding up its spoils to the main cylinder which draws them out still further. On the common roller carding machine workers and clearers alternate over the whole of the upper circumference of the main cylinder, down to almost the point at the back where the doffer cylinder comes into contact.

Doffer Cylinder.—Scarcely half the diameter of the main cylinder, the doffer cylinder resembles in shape and action the worker roller. Its teeth are inclined to the direction opposite from its revolution, which is the same as that of the main cylinder, and at the rate of 70 ft. per minute. Being set close to the main cylinder, the teeth of the doffer pick from it the carded cotton, condense it, and carry it off, round under and up on the side farthest from the cylinder.

Doffer Comb.—Across the whole length of the doffing cylinder, working on two cranks and guided by a pair of arms, is the toothed steel blade known as the doffing knife. By means of the arms and cranks a tangential motion is imparted to the knife, which plays upon the doffing cylinder, clearing off the cotton in a filmy web. "This", says Dr. Ure, "is the crank and comb contrivance so unjustly claimed for Hargreaves in the lawsuit against Sir R. Arkwright. This elegant instrument takes off the cotton in a fine transparent fleece, like the aerial web or woven wind of Aurungzebe's daughter." We have improved upon Arkwright's invention by discarding the crank and crank arms and simplifying the mechanism; but the principle is the same.

Sliver-forming Apparatus.—At the end of most cotton carders a sliver-forming apparatus is placed. This consists of a guide plate, a condensing tube, condensing rollers, twisting plate and rollers,

coiling disc and tube, and revolving sliver can. The guide plate is so formed as to collect the wide filmy web into a single mass, which fits into the wide trumpet mouth of the condensing tube. The condensing rollers are weighted, bearing down upon the cotton, and flattening it into a riband. In the plate before the coiling rollers is a small circular hole which changes the form of the riband, and the coiling rollers, held a little apart, add the touch which converts the soft material into the form of a rope. As a rule the coiler rollers have a quicker motion than the compression rollers, making a gain of 12 in. per minute, and therefore elongating the sliver. The draw-box draft, as the technical term is, helps to redress any overlapping of fibres which may have taken place in the condensing operations. Above the revolving sliver can is a disc, with a curving tube in the centre of its revolution. As the disc turns round it imparts a slight twist to the soft sliver and lays it in a coil in the can. The revolution of the can itself widens the circles of the layers of sliver, piling them up in a series of cycles within itself.

Operating the Roller Carder.—Having set the rollers and cylinders to his satisfaction, and laid the lap in position, the carder puts on the drive. Lap roller and feed roller start simultaneously, and as the broad fleece issues from beyond the grip of the latter, it is struck downwards and inwards by the saw-tooth wires of the licker-in roller and carried on to the main cylinder, the hooked wires of which, by their superior speed and greater closeness, seize and distribute the loosened tufts of cotton. The swift stroke of the licker-in teeth sends the small particles of hard grit and dirt, which have been too small for the scutcher, down upon the grid below the roller.

The fibres of cotton lie lightly on the surface of the cylinder and come within the hooking teeth of the dirt roller while being borne swiftly round. The fine teeth of this roller search the cotton for particles of broken leaves, motes, and knotted fibres, and hold them while the toothed blade of the knife scrapes off the cotton and gives it back to the cylinder.

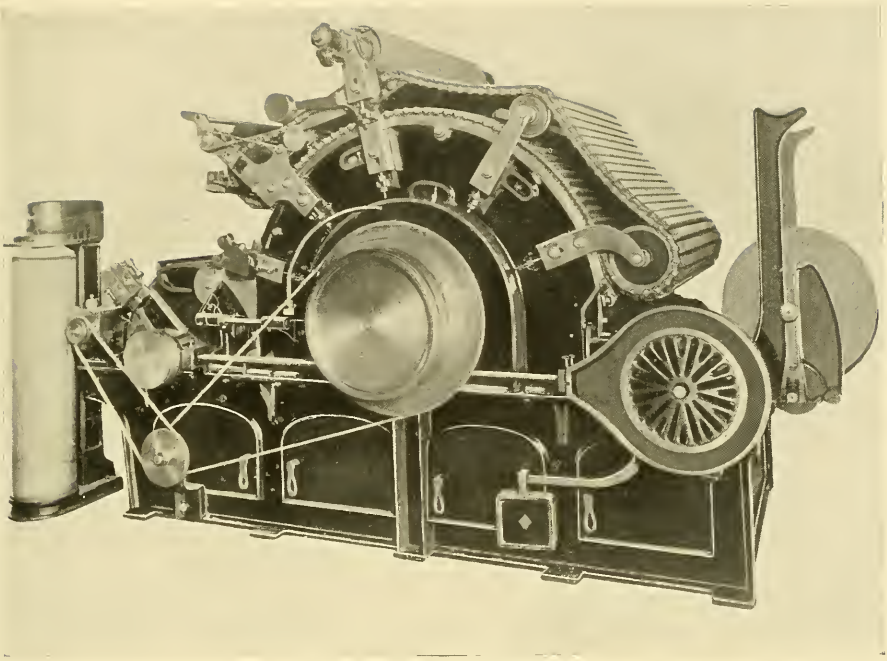
Flying at the rate of 1600 ft. per minute, the main cylinder combs out the cotton finely while the worker holds them; the latter finds many fibres bulging out, twisted, and snarled, and lifts them off with its teeth, clothing itself with the white flakes. But as the worker begins to accumulate a small store of cotton in its slow deliberate manner, the smart little clearer comes flying round and draws the cotton out of the teeth of the worker, drawing the fibres

at the same time. The clearer does not retain its spoil, for the teeth of the great cylinder coming after at greater speed denude the little roller. Again the next worker gathers the loosened material to itself, carding and condensing, and again the clearer strips the worker bare, resigning in turn its capture to the main cylinder.

By this action and interaction of the triple agency the cotton is cleaned, carded, and unravelled, and the fibres laid in parallel order. At the end of the series of workers and clearers the cylinder is clad with a thin but regular fleece of cotton, and this the doffer proceeds to take off and condense with teeth steadily opposed. Clothed with the fleece of carded cotton, the doffer cylinder revolves and comes into contact with the steel blade of the doffing comb. Playing with a vibratory and tangential motion on the surface of the cylinder, the knife slices the cotton from the cylinder and delivers it forward to the guide plate beyond in the form of a soft, fleecy cloud.

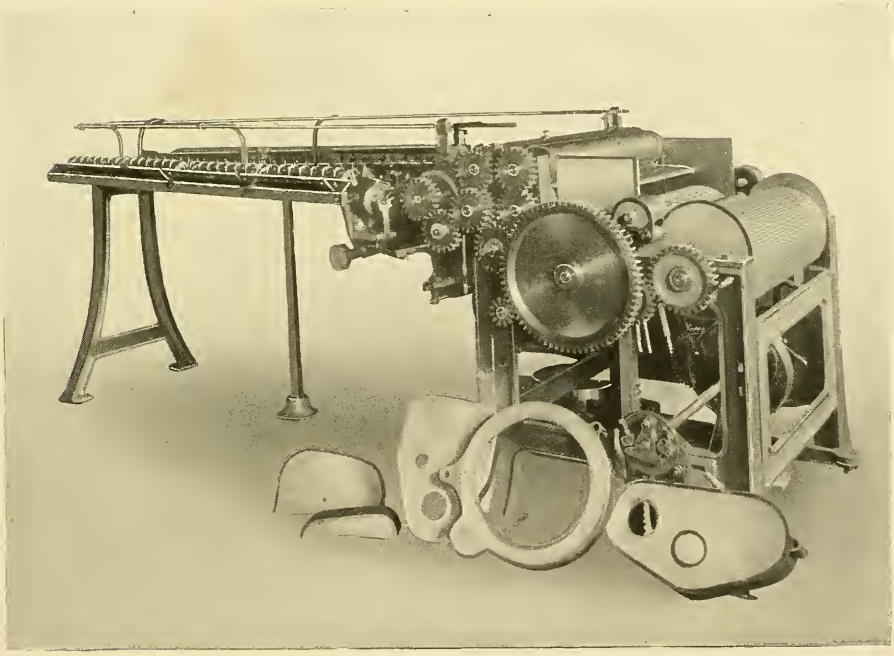
Drawn together slightly on the guide plate, the fleecy material passes easily into the open mouth of the trumpet-shaped tube, and thence in between the condensing rollers, issuing from their pressure in the form of a flat riband. Elongated about 20 ft. in every 100 by the rollers of the coiler, and made round by their action, the cotton is dropped into the can a finished sliver. It is by no means contended that the roller carder achieves all the spinner desires. On the contrary, the defects of the machine have stimulated invention, as the Wellman flat, the revolving flats, and many another kind of carder show. But as breaker card, and for coarse cottons, waste, and slivers for low counts, no better machine has been invented. We view it in the latter capacity.

Wellman Flat Carder.—Lewis Paul conceived the idea that by placing the cotton between two sets of cards, at equal distances from each other, the one stationary and the other moving, carding could be effected. This idea has never been wholly abandoned; in some form or other it has always been present in the carding rooms of the cotton trade. Arkwright used a set of stationary flats. A stationary set of flats was tried on the top of the carding cylinder, with rollers combined, and it was certainly an efficient engine; but the flats were continually clogging, compelling a long pause for cleaning. The flat card was so profitable that hand strippers of high skill were employed to clear the clogging cotton from the tops while the machine was at work, but the manufacturers, esteeming the card strippers mere labourers, reduced their wages to the level of other machine



FLAT CARDING ENGINE

(J. Hetherington & Son, Ltd., Manchester)



DERBY DOUBLER

(J. Hetherington & Son, Ltd., Manchester)

minders, and skilful, able men deserted the trade. Flat carding consequently fell into disrepute, and the roller carding engine became for a time the chief tool of the carding room.

In America, however, the problem of dispensing with the card stripper was energetically tackled, and a citizen of the United States, named George Wellman, adapted Arkwright's carding flat to the form now known by his name, inventing a method of automatic stripping. The Wellman self-stripper carding flat was brought over to this country, and, after being improved in various particulars, was accepted in Lancashire. A series of flats, the breadth of the common card strip, and clothed with fine card cloth, are placed side by side so as to form a long sheet capable of covering the upper circumference of the main cylinder. Fitted upon adjustable brackets, the flats are bent concentrically over the face of the cylinder, and parallel at every point, the space between being determined by the class and length of the cotton to be carded. When the cotton has been given over to the main cylinder by the licker-in, it is borne in under the flats, the teeth of which hold the fibres while the cylinder combs them.

Flat Stripper.—The action of the Wellman carder, with the exceptions indicated, is the same as that of Arkwright's carder. The special feature of the machine is the stripping apparatus. At the end of a lever arm, which can move all over the semicircle of flats, the stripping apparatus is fixed. The lifter turns over the flat to be stripped, and the stripper roller then clears the accumulations of dirt and hardened cotton which have gathered upon it. When the cleaning action is done, the stripper restores the flat to its place and moves on to the next. The order in which the cards are to be stripped may be arranged beforehand. When they have been set to a given order the stripper passes unerringly from one to another, taking each in turn. Kept constantly going, the automatic stripper prevents the accumulation of dirt which would otherwise prevent a mechanism so delicate from performing efficiently.

The Revolving Flat Carding Engine.—Undoubtedly the highest and most efficient form of carder is the revolving flat carding engine. Completely equipped in every requirement, it works longer without attention than any other, and produces the finest sliver. Leaving aside the accessory parts for the moment, we examine the revolving flats. Differing little in essential character from the Wellman flats, though much smaller, the flats on this engine are formed into an endless lattice, stretched round the main cylinder by rollers supported

on adjustable brackets (fig. 69). As the flats pass over close to the cylinder they rest upon semicircular guide plates, set upon movable screws in the sides of the frame. The part of the lattice passing over to make the circle is held up by carrier rollers. Having the same office as the stationary flats, the revolving flats are not given a rapid revolution, the traverse being at the rate of 1 in. per minute. But the flats come round inch by inch, and as one comes up from operating it is brought into touch with the stripper roller, which is ready for it. Before the flat has passed on, the stripper has cleansed it clear of dirt and rubbish. In the centre of the machine, supported on a high bracket, sits the flat grinding roller, clothed with emery. The gradual movement of the cards gives the roller just the motion needed for its work. Row by row the points of the card clothing are renewed.

Other two grinding rollers work on this machine, the one on the main cylinder and the other on the doffer cylinder, but these can only be used after carding has ceased. With the work of repair and renewal constantly going on, the revolving flat carding engine maintains a high level of efficiency.

The Newest Carding System.—Equipped with the improved and very efficient revolving-flat carding engines, manufacturers have boldly adopted a system of carding with one engine only. Messrs. Platt Brothers & Co. assert that the "breaker and finisher system has become obsolete". From the machinist's point of view, they may be approximately correct, because new mills are being equipped on the single-carder system; but from the operative's standpoint the case is quite different. Old mills spinning low-grade cottons continue to use the breaker and finisher cards, running tandem or singly, with the Derby doubler. If the cotton is of the finest grade, the single-carder system is to be preferred; but a great number of mills are employed upon cottons which are not fine.

The Derby Doubler.—To carry the cotton direct from the breaker to the finisher without the intervention of a sliver, or even of a lap, the double carding engine was contrived. Between the two main cylinders a doffer cylinder was placed, the cotton passing from the doffer on the first carder to the licker-in of the finisher. We do not condemn the system, nor say that the double carder is obsolete, because spinners of coarse cottons still find those machines useful.

For low-grade and waste cottons a better plan is to complete the whole operation of forming the sliver on the breaker and start afresh on the finisher. This requires that the slivers formed on the first

carder must be remade into a lap for the finisher. To carry out that system the Derby doubler was invented. An additional advantage is the mixing of the cotton effected in the process. In front of a V-shaped table any number of cans, from twenty-two to sixty, are arranged, and the slivers led through curved hooks up to a series of rollers which break up the ropy form of the slivers and send the cotton on to

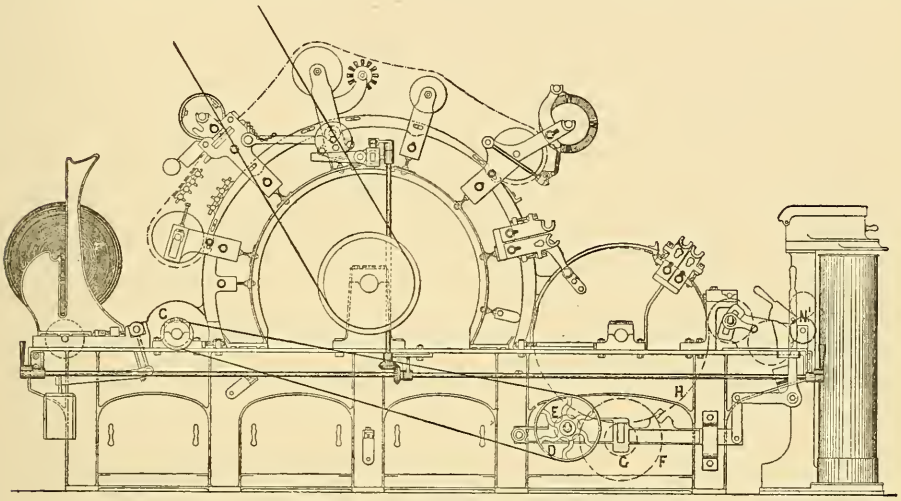


Fig. 69.—Elevation of Flat Carder (right side)

References to Letters on Figs. 69, 70, 71

Taker-in and Doffer Driving.—A, Taker-in driving pulley, 14 in. to 18 in. diam. B, Taker-in pulley, 6 in., 7 in., or 8 in. diam. C, Doffer driving pulley on taker-in shaft, 5 in. diam. (varies from 3½ in. to 6 in.). D, Dandy pulley, 10 in. diam. if 27-in. doffer, 12 in. diam. for 24-in. doffer. E, Change wheel on dandy pulley boss, 18T. to 50T. F, Wheel on 2nd stud, 40T. or 100T. G, Wheel on 2nd stud, 20T. or 40T. H, Doffer wheel, 216T. for 27 in. doffer, or 192T. for 24 in. doffer. Diam. of doffer, 24 in. or 27 in.

Feeder Driving.—I, Doffer bevel wheel, 30T. or 40T. J, Side shaft bevel wheel, 40T. K, Side shaft change bevel wheel, 9T. to 32T. L, Feeder plate bevel wheel, 120T. M, Feed roller pinion, 17T. N, Lap roller wheel, 48T. Diam. of lap roller, 6 in. Diam. of feed roller, 2¼ in.

Calender, Coiler, and Can Driving.—N[1], Calender pinion, 30T. O, Calender coupling wheels, 32T. P, Calender rollers, 4 in. diam. Q, Calender wheel driving coiler, 31T. R, Coiler cannon shaft wheel, 15T. S, Coiler cannon shaft mitre wheel, 20T. T, Coiler upright shaft mitre wheel, 20T. U, Pinion on upright shaft, 38T. V, Coiler tube wheel, 106T. W, Top bevel wheel on coiler upright shaft, 16T. X, Combined bevel and spur wheel on coiler calender, 16T.; S.W. 24T. Y, Coiler calenders, 2 in. diam. Z, Pinion at bottom of coiler upright, 16T. *a*, Double carrier wheels on stud, 48T. and 16T. *b*, Double carrier wheels loose on upright shaft, 48T. and 14T. *c*, Can dish wheel, 82T. *d*, Carrier wheels on radius bar, 19T.

Flat Driving.—*e*, Driving pulley on cylinder shaft, 6½ in. diam. *f*, Box pulley on stud, 12 in. diam. *g*, Single worm on stud. *h*, Single worm wheel on inclined shaft, 24T. *j*, Single or double worm on inclined shaft. *k*, Single or double worm wheel on notch block shaft, 40T. *l*, Band pulley on stud, 3½ in. diam. *m*, Band pulley on 4 row brush, 8 in. diam.

Fly Comb Driving.—*n*, Band pulley on cylinder shaft, 18 in. diam. *o*, Band pulley on carrier stud, 6 in. diam. *p*, Band pulley on carrier stud, 12 in. diam. *q*, Band pulley on fly comb spindle, 4 in. diam., range 3½ in. to 5 in.

a set of lap-making rollers. Each sliver has a stop motion applied to it, and when one breaks, the machine stops. The laps are made to half the breadth and weight required for the finisher card.

Draft.—The difference between the length of the lap and the length of the sliver is described as the *draft*. During its course through the

roller carding engine we saw the cotton alternately drawn out and condensed, but the draft is actually determined by the difference between the speed of the feed roller and the calender rollers driven from the

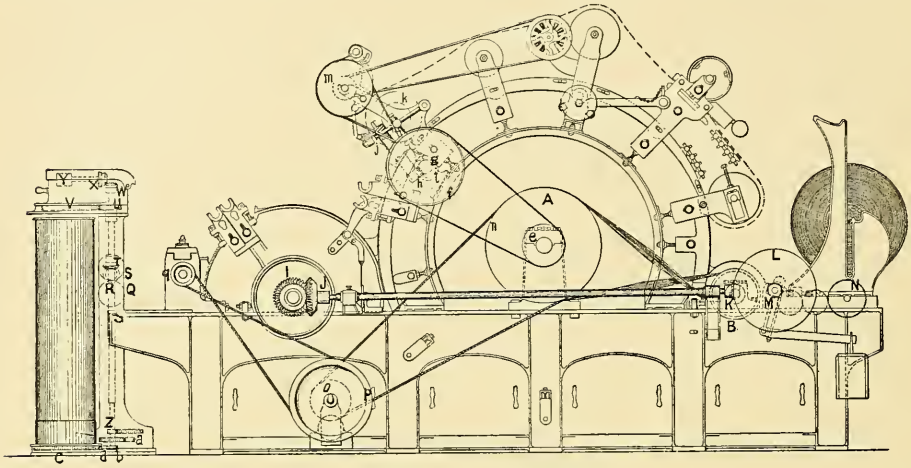


Fig. 70.—Elevation of Flat Carder (left side)

doffer shaft. We have therefore two methods open to us of changing the weight to length of the sliver. By increasing the number of teeth on the pinion driving the feed roller the amount of lap fed is increased

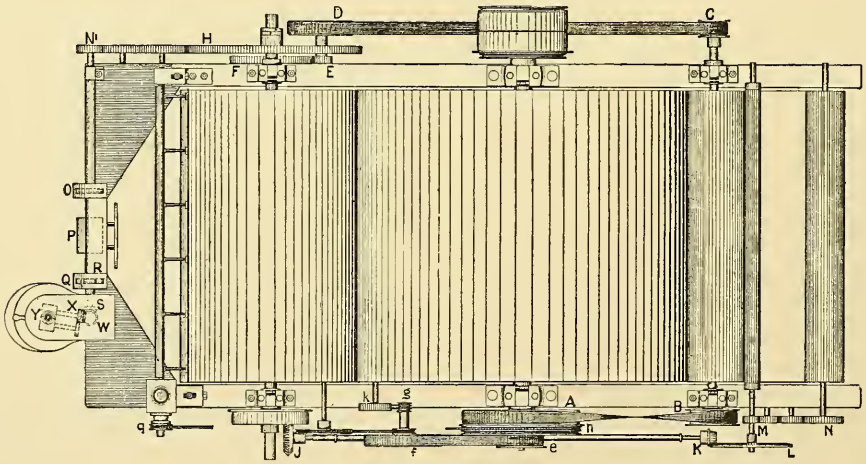


Fig. 71.—Plan of Flat Carder

and the weight of sliver made correspondingly heavier. If the number of teeth in the pinion on the doffer shaft driving the calender rollers is increased, the sliver will be lighter. Reversing the action in both cases

will produce the opposite effect. In calculating drafts, about 5 per cent should be allowed for waste.

Useful Carding Statistics.—The number of wires in each card is calculated according to an old system, in which the unit was a length of 4 in. on a card sheet. Normally, the finer the cotton the finer the teeth in the card clothing. A well-known firm of machinists gives the following:—

	Class of Cotton.	Cylinder.	Doffer.	Tops.
Surat ...	Lowest class ...	80s	90s	70s
	Better	90s	100s	80s
American ...	Lowest	100s	110s	100s
	Better	110s	120s	110s
Egyptian ...	Ordinary... ...	110s	120s	110s
	Better classes ...	120s	130s	120s

For a cylinder 50 in. and a doffer cylinder 24 in. in diameter the following lengths of wire filleting, plus an allowance of a few feet for waste, are given:—

Width on Wire.		Cylinders.		Doffers.
38 in.	.....	248 ft.	.....	159 ft. 0 in.
41 ,,	.....	268 ,,	.....	171 ,, 6 ,,
45 ,,	.....	294 ,,	.....	188 ,, 0 ,,

For the same machines the average weight of clothing has been given as follows:—

Width on Wire.		Tops.		Cylinders and Doffers.		Total.
38 in.	.....	$29\frac{1}{4}$ lb.	.....	81 lb.	.....	$104\frac{1}{4}$ lb.
41 ,,	.....	$31\frac{1}{2}$,,	.....	$87\frac{1}{2}$,,	.....	119 ,,
45 ,,	.....	$34\frac{1}{2}$,,	.....	96 ,,	.....	$130\frac{1}{2}$,,

Wool Carding.—The process of separating the wool fibres is very closely graduated. Sudden changes in treatment are not permitted in the manipulation of wool. Because this fact was ignored by the men who first attempted to introduce the carder into the woollen factory, great disappointment was experienced. For almost a century after the usefulness of the carding engine had been fully proved, hand cards and stock cards continued to be the sole instruments employed for separating the fibres in many woollen factories. By a large number of woollen workers and not a few manufacturers the carder was regarded with mingled suspicion and contempt. They had seen the costly machine breaking and tearing much good wool; but it was the cotton carder which had been found a failure. The fine and regular

teeth, the uniform action of workers and clearers, combined with the straight draft of the main cylinder, acted too severely on the wool. Further, the fibres were doubled and broken by the close interchanges between the various parts of the carder. Yet the whole preparatory process of woollen manufacture is a series of carding operations. Take the teeth of the opener, the rollers of the burring machine, and the teeth of the Fearnought, and you will find there a series of rude card teeth and cylinders. In these appliances the carding principle is contained. The failure of the first attempts to utilize the carding engine in woollen manufacture was due to an error of judgment, not to any inherent unsuitability of the machine.

We do not know whether it was from a perception of the facts we have noted, or from persevering experiment, that the wool carder was evolved; but it certainly came, and has since established itself as one of the essential instruments of wool manufacture. In a general way it may be said that the wool carder is the epitome and refined embodiment of all the preparatory machinery which was in use before it. At the fore end of the machine the card clothing is coarse, strong toothed, and tearing in its action; in the middle the card clothing is finer; at the end the action of the machine is pure carding performed by fine card clothing.

Aims of Wool Carding.—Before going on to examine the carding engine in detail, we may devote a little attention to the objects aimed at in wool carding. The first and simplest objective of the carder is the separation of all the fibres from one another. From an examination of the wool as it comes from the Fearnought teaser we learn that most of the staples or locks have been merely subdivided, and that sections of the fleece still preserve their original natural relations. If such a state of things were allowed to continue, a very poor kind of thread would come from wool spinning. Every single hair of wool must be made to separate itself from every other, so that it may freely obey the direction of the process of thread-building and take its proper place in the yarn. A consequence of this condition is the intermixing of all the fibres. Drawn apart, the fibres enter into new combinations. The third object in carding is the straightening out and cleaning of the wool, the taking away of all knots, snarls, and dirt. One aim of the cotton carder is not an object with the wool carder; in carding cotton we desire to bring all the fibres as nearly parallel as possible; the wool carder has no such aim. On the contrary, if, after the fibres have been fully separated from each other, they can be closely combined in a

smooth and uniform sliver, with crossings and intertwinings, so much the better. Where the parallelism of wool fibres is desired, a different kind of machine is employed. An attempt to produce such an effect by means of the carding engine would involve a total change in its structure. In view of the fact that cotton carding lays the fibres parallel, some explanation of the inability of the wool carder to effect the same purpose seems to be needed. Many explanations are possible. For example, the fibres in one staple of wool vary considerably in length; to lay them parallel the fibres must be drawn out to their full length. If the carding rollers were to draw out the longer fibres fully, the shorter fibres would drop out and cause endless trouble. As we have said, however, the essential character of a woollen thread, and, in consequence, of the sliver, is its crossed and felted quality, the ends of the fibres pointing in any and every direction.

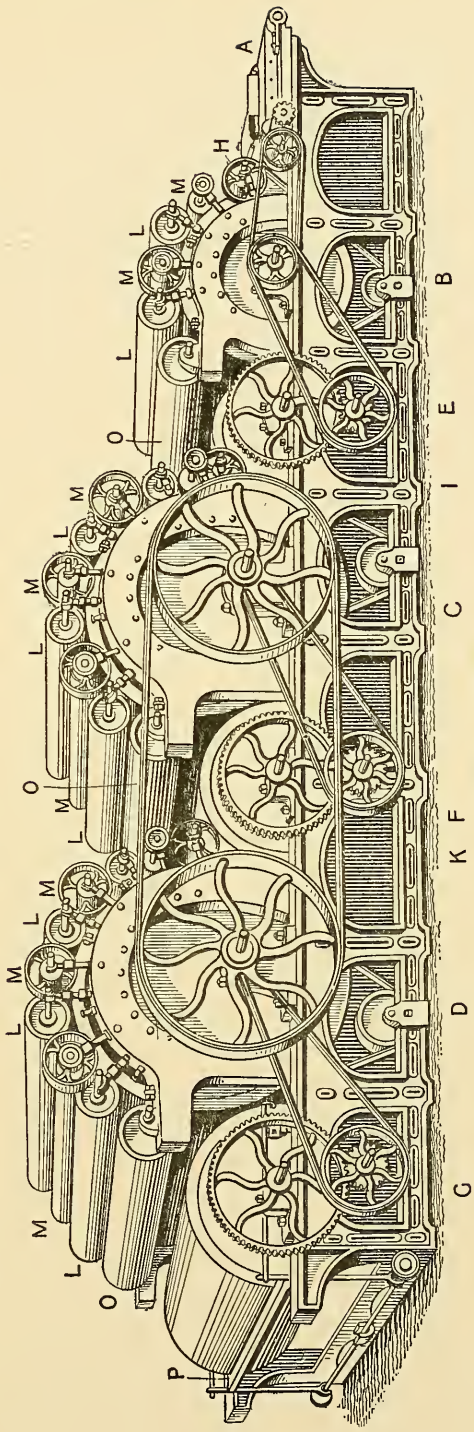


Fig. 72.—Scribbler

A, Feed sheet. B, Breast cylinder. C, First main cylinder or swift. D, Second main cylinder or swift. E, F, G, Doffers. H, I, K, Angle Strippers. L L, Workers. M M, Strippers and their driving pulleys (for the sake of clearness the gearing of these small rollers is omitted, as is also the clothing of all the rollers). O O, Fancy or fly rollers. P, Doffing comb.

The Wool-carding Engine.—The first carder, better known in the trade as the *scribbler* (fig. 72), is the typical and representative wool-carding engine. One of the largest and heaviest of textile machines, it is also one of the most efficient. The scribbler commonly employed in this country, and by all classes of manufacturers, consists of three cylinders, with feeding and doffing apparatus, and the numerous small rollers which card the fibres over the cylinders. This large structure contains many parts which can only be fully understood by detailed examination. We take the parts one by one.

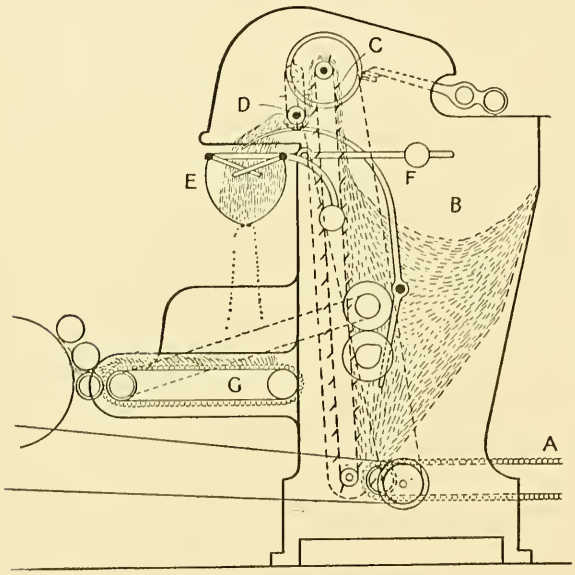


Fig. 73.—Bramwell Automatic Feed

A, Lattice feed. B, Hopper. C, Spiked carrier. D, Stripper apron. E, Weighing pan balanced by the weight F. G, Feed lattice of carder.

Bramwell Feed (fig. 73).—When the wool comes from the Fearnought teaser it is a mixed mass. On the feed board of the carding engine without the mechanical feed, spaces are marked for the guidance of the hand feeder, indicating the weight of wool covering a given space. A careful and skilful worker can feed accurately under these conditions, but the work is difficult. With the Bramwell apparatus it is possible to feed into the scribbler exactly the weight of wool designed. Contained in a metal case, the instrument is placed in front of the feed lattice of the carding engine, and the driving pulleys of the feed aprons connected up with the drive of the machine.

An open hopper, with grid bottom, a toothed apron, an oscillating comb, a stripper apron, and a weighing board, constitute the Bramwell automatic feed, and these operate in the following manner: A supply of wool is laid in the hopper, and the belt put on the driving pulley. The apron, the teeth of which are hooked, takes upon itself as much wool as it can carry; the oscillating comb working over it moderates the zeal of the apron by combing away the superfluous wool it bears;

carrying a smoothed sheet of wool, the endless apron turns down and comes in contact with the stripper apron, which, running at a greater speed, strips off the wool and sends it down into the weighing scale. Balanced on knife edges and controlled by weights, the weighing board tips up as soon as the desired quantity has been laid upon it. In doing so it performs a double action, releasing the small trigger arranged to knock off the drive and letting the wool fall down on the moving feed lattice of the scribbler.

The Bramwell feed has been called into requisition by manufacturers of various textiles, one of its most useful applications being in the waste-silk industry.

Feed Rollers.—The feed lattice is the same endless belt as we see on nearly every machine of the class, but the feed rollers are special and peculiar. The wool manufacturer has found that an effective method of mixing is to send fibres lying together in the raw state away in different directions on the machine, and the feed rollers of the scribbler carry out the idea. Three in number, clothed with card teeth, and placed one above the other, the feed rollers part the wool among them, opening it out before passing it forward. Only the lowest of the three sends the wool through directly, the upper two playing with what portion they can secure, and so pulling asunder the locks of fibres.

Licker-in.—Behind the feed rollers, revolving towards them, with teeth bent in the direction of its revolution, is the roller known as the licker-in. When the wool projects beyond the feeding rollers the licker-in drags the fibres away.

Angle Stripper.—In some machines the licker-in acts directly on the breast cylinder, which is revolving all the while behind the mechanisms we have been looking at; but the best practice is to make the angle stripper act as the medium between the cylinder and the licker-in, thus avoiding all risk of breaking the fibres by too close feeding. The teeth of the angle stripper very literally strip the licker-in and throw the wool on to the adjoining breast cylinder, having little power of retaining the fibres.

Workers and Strippers.—These rollers are of the same structure, action, and function in all kinds of carders. Size is a varying factor, fixed according to the length and thickness of the fibres. Workers on the wool carder are 8 in. in diameter; strippers are usually between 3 and 5 in. The workers pick the wool from the cylinder, and the strippers return the wool. The number of workers and strippers on

a cylinder is proportioned to its size. On the small cylinder, designated the breast cylinder, there are usually two pairs; on the larger cylinders five pairs are common. The card clothing of these rollers is coarse or fine, according to the class of wool which is to be carded, and the position relative to the cylinder is gauged by the length of the fibres and the stage of carding.

Fancy.—The fancy, or fly, is a roller peculiar to wool carding. In form, function, and clothing it differs greatly from any other carding roller. The wires are fully twice the length of the longest wires in common card clothing, and bent at a very slight angle opposite to the direction of its revolution. The fancy resembles rather a fine metallic brush. Workers and strippers are not allowed to come within touch either of each other or the cylinder over which they revolve, but the fancy must touch, though lightly, the surface of the cylinder. Another matter in which this roller is singular is its speed. The whole plan of the carding engine has been arranged so that the main cylinders alone require to be brought up to a high rate of speed; but the fancy is the exception. In order to understand the reason for this we must learn what is the function of the fancy. By the action of workers and clearers, or strippers, the wool has been smoothed down on the cylinder till almost embedded in the wires. Were the doffer burdened with the duty of taking off the wool in that condition, it would require to be very much altered in structure and character. The change is not impossible, but an easier way of getting over the difficulty was the introduction of the fancy. Driven at higher speed than the cylinder, furnished with points long and flexible, set almost in touch with the clothing of the cylinder, the fancy picks into the wool on its surface and loosens it. The points of the fancy are not deflected much from the straight line, because it is not meant to retain any wool. All we require from that roller is that it lightly loosens, pulls out, the wool on the surface of the cylinder, so that the doffer may find the work of taking away the fibres an easy task. The revolution of the fancy is such as to overtake and pass the cylinder, and it therefore unhooks the fibres from its teeth, leaving them free for the doffer.

Doffers.—Though we consider it as an auxiliary, the doffer is very nearly equal to the breast cylinder in size. For fine wools the doffer is seldom more than 24 in. in diameter, but on carders working coarse wools the diameter is frequently 36 in. Revolving in upon the cylinder, the card-clothing points directed contrary to its revolution,

and set close in to the side of its large neighbour, the doffer takes away the wool and carries the fibre down on itself in an even sheet of fleece.

Doffing Knife.—The toothed blade of steel, controlled by arms which lift and draw down with tangential motion, is the same on all carders. In adjusting the doffing comb on the wool carder, however, some attention must be paid to regulating its speed and length of stroke. For fine short wool the lift should be long; to comb off long or coarse wools the stroke should be short and quick.

Cylinders.—At present we leave aside the delivery of the carding engine, because the form of it depends on factors we cannot yet take into account. On the scribbler commonly employed there are three cylinders, the breast cylinder and two main cylinders or swifts. Smaller than the other two, the breast cylinder ranges in size from 36 to 38 in. in diameter, and has two sets of workers and strippers operating upon it, with, of course, the fancy and doffer roller. The two main cylinders, technically named swifts, placed in succession with a doffer between, are very large, being 48 in. in diameter. Over each of these, five or six sets of workers and strippers play the seizing and giving game with the wool, and from both the fancy picks up and the doffer draws off the carded fibres.

All the cylinders revolve away from the feed of the machine. The card clothing of rollers and cylinders is gradually made finer towards the end of the scribbler.

Card Setting.—All the rollers are carried on adjustable bearings, and it is a constant problem how to set each roller in the relation to the main cylinder which the length of the fibre requires. A French investigator, M. Charles Leroux, has given a series of tables which may be taken as the best available guide to a solution of each problem. Nothing can be accepted as a substitute for careful observation in practical experience, but M. Leroux's table on next page may be accepted as a help. The tables are based on the metric system, and the unit is the millimetre.

Operation of the Scribbler.—Having seen all the working parts of the large machine we are now in a position to understand its way of working. Dropped into the hopper of the Bramwell feed, or, it may be, spread under the hand of the machine minder, the wool passes along the feed sheet, or endless lattice, and is borne forward to the triple set of feed rollers. The bottom roller divides the fibres fed with the middle roller, and the top roller grips on to a share from the roller

CARD-SETTING TABLE

Names of the Rollers.	Wools.					
	Superfine and Short.	Fine.	Semi-fine.	Medium.	Coarse.	Very Coarse.
1st Breaker—						
Feed rollers ...	2.3	2.5	2.7	3.0	3.3	3.6
Licker-in	2.2	2.3	2.5	2.8	3.1	3.4
Angle stripper ...	1.8	2.0	2.2	2.5	2.8	3.1
Main cylinder ...	Basis from which intervals are measured.					
Strippers	1.2	1.3	1.4	1.7	1.9	2.1
Workers	1.1	1.2	1.3	1.6	1.8	2.0
Fancy	Scarcely touches.					
Doffer	1.0	1.1	1.2	1.5	1.7	1.9
2nd Breaker—						
Feed rollers ...	2.2	2.4	2.6	2.9	3.2	3.5
Angle stripper ...	2.0	2.2	2.4	2.6	2.8	3.1
Main cylinder ...	Basis from which intervals are measured.					
Strippers	1.5	1.2	1.3	1.5	1.7	2.0
Workers	1.0	1.1	1.2	1.4	1.6	1.8
Fancy	Scarcely touches.					
Doffer	0.9	1.0	1.1	1.3	1.5	1.7

below, winding it round itself. But the effort of the other two rollers is to push the wool forward, and they succeed in bringing the divided and opened material within the points of the licker-in revolving between them and the breast cylinder. The licker-in quickly draws to itself the wool protruding from the feed rollers and bears it away. At the same moment, however, the angle stripper, following hard after, with high speed and long teeth, takes charge of the wool, relinquishing it in turn to the breast cylinder, the teeth of which come swiftly after those of the angle stripper in the same direction, like the racer who takes the lead from his slower competitors.

The breast cylinder has hardly got possession when a worker roller, turning slowly above it, catches on to the loose open fibres held in the wire teeth of the cylinder, quietly teasing them out. Like a watchful satellite a stripper roller follows after and overtakes the worker, and, its teeth having, at the moment of contact, the same inclination as those of the slower roller, lightly picks up and lashes out the wool. But the breast cylinder has the same advantage over the stripper as the latter has over the worker roller, and so it resumes possession of the fibres once more. Another worker a little farther round the cylinder again brings opposing teeth to bear, and the interchange of wool is repeated. Still the heavy breast cylinder pushes the wool onwards, making it lie closer and closer in smoother and smoother condition among its

teeth; but a fancy roller, with long teeth and swift motion, loosens up the wool from the cylinder, then the doffer, rolling slowly below and meeting the teeth of the cylinder point to point, lifts away the carded fibres.

At this point the doffer roller acts simply as a larger worker, and has the same experience; for an angle stripper revolves behind it and thoroughly clears it of wool, acting the feeder to the first of the two main cylinders or swifts, running at high speed very closely adjoining. This great carding tool deprives the stripper of its spoil and flies off with the wool. Over the cylinder, however, a close array of workers and strippers are hungrily awaiting the prey. Circling among them the wool is dragged, drawn, opened, straightened, and cleansed, the workers stubbornly refusing to let a single obtrusive fibre pass. Driven onward by the heavy weight of the mighty swift, the wool at last gets through, and comes within the quick pecking touches of the fancy. Thus loosened from the hold of the swift, the wool is taken off by the doffer.

The second swift, equally large and powerful, takes the wool through another series of operations similar in every respect to the foregoing, but with keener teeth on rollers set closer to the cylinder. After the wool has passed from this cylinder on to the doffer it encounters the close attentions of the doffing comb, which shaves down upon the doffing roller and slices off regular strips of fibres on to whatever kind of delivery apparatus may have been provided. That the modes of delivery are various we have already hinted, and these may be examined in the next stage of the operations.

Of the effectiveness of these operations there can be no doubt. On every batch of wool passing through the scribbler just described 5,000,000 points operate, searching keenly into every twist and knot in the crinkling, curling wool, straightening out every tangle and snarl in every lock of fibre. Yet it is only a beginning of the carding process.

After the Scribbler.—Some objection has been made to the severe action of the scribbler, and the objection has a basis in fact; but the tendency has been to employ the machine more and more on every kind and class of wool in every department of the industry. Felt, woollen, and worsted manufacturers, including spinners of yarns for hosiery and carpets, have called the scribbler into their service. Standing at the end of the scribbler, therefore, we have to witness a wide distribution of the material issuing from it. Part of the scribbled wool goes directly into the felting machines; part is passed on to the comb-

ing machines in the worsted factory, where the gilling machines prepare the finer and longer wools; and the greater part is taken to the next carding engine for woollen purposes. Felt manufacture and worsted combing require to be treated separately and at length; meanwhile we follow the woollen carding through to a finish.

Systems of Carding.—When recording the operations in a developing industry we are constantly faced with the difficulty of grouping in a systematic manner the numerous variations in actual practice. Carding, as understood by the great majority of British woollen manufacturers, consists in the regular operation of three carding engines: the *scribbler* or *breaker*, the *intermediate*, and the *finisher*, each having two swifts. For a large variety of work, ranging from very coarse to very fine, this system is still held to be the best; but the economizing genius of America dispenses with one of the swifts in each engine, lessening the amount of driving power and space required. For medium and fine counts of yarns the single-cylinder machines have been found to answer very well. Again, while using the common scribbler, some manufacturers have adopted the American intermediate and finisher engines. Yet another practice is to dispense with the intermediate altogether. We do not undertake to commend one system above any other; our business is to record the facts. It may be said, however, that the older system really includes all others, the latter being merely modifications of the former, and the man who knows the two-cylinder scribbler, intermediate, and finisher can easily comprehend all the others.

We have also to note, however, the advent of new forms of carding engines. Machinists have attempted, with some success, to lessen the importance of the strippers and increase the diameters of the workers. In several new machines the strippers are merely very small auxiliaries set between the large worker rollers. Hence it is necessary that the reader should always remember that when a particular machine is selected as the representative of an operation performed by other and differing machines, the principle only is being exhibited, not the final and perfect machine.

Methods of Delivery and Feed.—The method of delivery from the doffer on the scribbler wholly depends upon what form of feed we intend to adopt in feeding the carding engine succeeding. Three methods are commonly used: the *lap*, the *Scotch feed*, and the *balling or side-drawing feed.*

Lap Delivery and Feed.—There are several forms of lap delivery

appliances, the best known of which is the Marsden and Blamire. A lattice, with a reciprocating movement, receives the thin layers of wool from the doffing comb and builds them together into the thickness required. Under this lattice an endless lattice runs in a transverse direction, carrying the wool up to a pair of rollers, which send it onward to the lap roller. The fibres which have left the scribbler lengthwise are thus built crosswise into the lap. In many felt factories no other form of delivery is used. It is also specially suitable for low-grade wools and where no intermediate carder is employed.

Scotch Delivery and Feed.—Where the intermediate carder is placed behind the scribbler this method suits well. Gathered from the doffing comb to a narrow band about 6 in. broad, the wool is passed between rollers which compress it to a narrower breadth and shape it like a broad riband. In this condition the wool is carried by a travelling lattice or band up above the feed board of the next machine, whence it is carried down into the conduct of a roller carrier, which pays it out on the feed lattice in layers, the motion of the lattice causing them to overlap, and thus presenting a level feed to the rollers.

Balling or Side-drawing.—The delivery apparatus of this feed closely resembles, in the beginning, the Scotch feed. The sliver is formed in a similar manner, but instead of passing on to a travelling lattice the compressed riband is drawn into a revolving tube and round a bowl or wooden bobbin, held between two winding discs (fig. 74). In a hopper above the discs a supply of bobbins is kept, and as one fills another drops down into place. A certain amount of twist is thus given to the sliver, and the fibres lie in the same order as when delivered from the doffer. The balls, or chases, are set in a rack, and then each is fed into the lap roller, passing thence on to the feed lattice of the next carder in a regular lap.

Intermediate and Finisher Carding Engines.—These machines are always equipped with card clothing much finer than that on the scribbler; but, as has been already hinted, there is no other uniform practice. Some intermediates have one cylinder only, with six workers and six strippers; single-cylinder finishers are not very uncommon, though rarer than single-cylinder intermediates. In any case the processes on both intermediate and finisher are just the same as we have seen on the scribbler. The wool is fed into the licker-in, thence to the angle stripper, and round among the workers and strippers, the game of give-and-take being constantly carried on till the weight of the great main cylinders or swifts shall have brought the material through. As

before, the fancy tips up the wool in preparation for the doffer, and the doffer takes it away, to be in turn despoiled by the doffing comb. The delivery and feed most generally to be found between the intermediate and the finisher is the Scotch feed, that method giving a regular fleece of wool to work with, and preparing for the condenser,

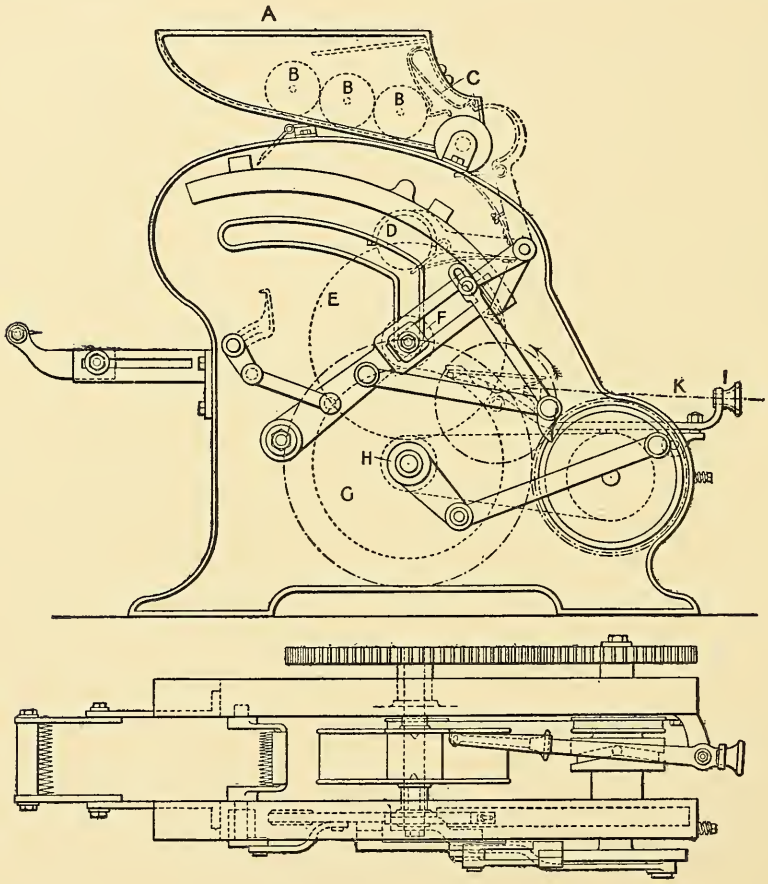


Fig. 74.—Ball Feed: Plan with upper part removed

A, Hopper. B, Empty bobbins. C, Spring. D, Bobbin falling. E, Disc. F, Spool in act of filling. G, Winding drum. H, Drive. I, Trumpet. K, Sliver.

which is usually at the end of the finisher. While the condenser figures often as an integral part of the last carder, it is a separate mechanism and demands consideration by itself.

Worsted Carding Engine.—The French system of worsted manufacture differs in several respects from the system commonly practised in this country. About the middle of the nineteenth century an enter-

prising firm of machinists brought over a set of worsted-preparing machines from France, and introduced them to the notice of British worsted-yarn manufacturers. Very few have accepted the system in whole, but many of the French worsted carders, partly modified, have been employed.

After being washed the wool is squeezed free of water, and in this wet state brought to the carder. The wool is spread by hand on the feed board, and carried by the lattice into the grip of the feed rollers. Behind the feed rollers the main peculiarity of the worsted carder occurs. Three burr rollers, with burr guards and trays, are here set. The first burr roller is 18 in. in diameter, and steam heated within; the second is half the size of the first, being 9 in. in diameter; the third roller is 12 in. in diameter. All three are clad with strong steel teeth, graded from very coarse on the first to fine on the third roller. The speeds of the burring cylinders are also graded, the highest speed being attained by the last of the series. The object of grading in both cases is to divide the burring labour, the first roller taking off the large burrs, the second the medium burrs, and the third the broken burrs, seeds, motes, and other small matters.

Otherwise the worsted carder closely resembles a scribbler, having breast cylinder, with three pairs of workers and strippers, and two swifts, each 50 in. in diameter, with four pairs of workers and strippers.

If the wool is too harsh and open, or thought to be in need of oil for other reasons, an oil-spraying apparatus is fitted up so as to spray the fibres with oil as they come from the last of the burring rollers.

It is on the end of the worsted carder that the balling delivery apparatus finds its proper application. The slivers formed pass directly on to the gilling machines, for which the ball form of feed is very suitable.

Speeds and Drafts on Carding Engines.—After he has solved the difficulties of setting, and generally adjusted the machine, the worker on the carding engine has other two problems to consider. Within obvious limits the carder is a mobile instrument. The speed relations of its various parts can be changed at will. In this we have a very important tool. From observation of practical working we find the following variation of speed measured by revolutions per minute: Main cylinder or swift, 60 to 100; workers, 5 to 10; doffer, 5 to 20. The mere structure permits the carder to run the cylinder at its highest speed, and the workers and doffer at any speeds he chooses. The aim of the carder, however, is always to establish the ratios of speeds which

produce the best results. The nature and class of the wool to be carded has to be considered before this can be accurately determined. On such a practical question only general rules can be laid down, every new blend of wool bringing its own set of problems. Two rules form the basis of practice: 1, For fine wools, cylinders running at high speed and workers at low speed give the best results; 2, for coarse wools slow cylinders and rapid workers is the rule. Slow workers and strippers keep the wool longer among themselves and card it out better, the rapidity of the swift assisting in the work. On the other hand, if we have high speed on the cylinder while working coarse wool the fibres are certain to break and fall away; but, as the coarse fibres do not need the same amount of carding as the finer material, the speed of the workers may be quickened.

One of the objects of carding is to draw out a given weight of fibres to a certain length. Say that 1 yd. of lap weighs 1 lb. and a sliver of 50 lb. to the yard is to be obtained. This would be called a 50 draft, and the delivering roller would require to run at fifty times the foot speed of the feed roller, and a little over, to allow for waste. To find the draft required, multiply the number of teeth on the driven wheels by the diameter of the delivering roller, and divide by the number of teeth on the drivers multiplied by the diameter of the feed roller.

Condensers.—In some respects the woollen thread is unique among textile yarns. In cotton, for example, the spinner asks for a sliver the component fibres of which are as nearly as possible parallel; he draws them out to a smooth thread, relying on the twine or twist, combined with the natural cohesiveness of the fibres, for tensile strength and coherence. When spinning woollen threads the procedure is quite different. We aim at making a thread full, soft, open, with the least possible twist, and yet strong in tensile power. Wool is soft, crinkled, and scaly; by crossing, interlocking, and felting the fibres together a strong and coherent thread can be made, a thread which retains all the qualities of softness and fullness we desire. The instrument almost universally employed in attaining this result is the condenser.

We have said that the purpose of the condenser is to produce a soft and felted thread. But, as it comes from the finisher card, the wool is in the form of a sheet, unless otherwise provided. The inventor of the condenser therefore aimed at two objects, viz. the division of the sheet of fibres into such parts as will form into a thread of the requisite fineness, and the condensation of those threads to a strong

FANCY COTTONS

1, Leno Spider Stripe. 2, Extra Warp Spots. 3, Check Zephyr. 4, Diagonal Check. 5, Brocade. 6, Fancy Twill Herring-bone. 7, Satin Stripe.

consistency. Up to the present time two solutions of the double problem have been at the service of the woollen industry. One is the original *condenser*, and the other is the *tape condenser*, invented by a Belgian named Bolette. Both these machines have been progressively improved, and machines of various grades are to be found in factories throughout the country. It is altogether misleading to take the latest improved model of any kind of machine and put it forward as the thing by which a given operation is performed, or a certain article is produced. It very frequently happens that the improved machine has never gone outside the works where it was made, and never performed a single day's work or produced anything.

There are at present working in the factories of this country four different condensers. These are: 1, *the single doffer and stripper*; 2, *single doffer and double stripper*; 3, *double doffer and double stripper*; 4, *the Belgian tape machine.* These machines differ only in the method of taking off and dividing up the wool from the carder; the actual operation of condensing is performed by all in the same way by the same appliances. To save repetition we shall examine the doffing and stripping arrangements of all four machines before considering the condensing apparatus.

Single Doffer and Stripper.—When the wool is taken from the main cylinder in a solid sheet, the doffer roller is wholly covered with wire clothing; but the doffer of the condenser is intended to deliver the carded wool in the form of slivers, or, at least, strips of wool of the size which is required for a sliver. To accomplish this the doffer is clothed with rings of card clothing, each ring being separated from the other by a space. As a rule, the rings on the doffer are $\frac{13}{16}$ in. wide, and the spaces between $\frac{3}{16}$ in. On an endless band strips of card clothing corresponding in width and position to the rings of the doffer run under the latter and strip from it the wool it has taken from the cylinder. From the strippers the lines of fibres are borne forward to the condensing rubbers; but there is a discrepancy here which must be attended to, and which helps to explain some of the improvements wrought upon the machine.

Say that the width of the cylinder is 72 in., the doffer rings only cover 58½ in., leaving untouched 13½ in. That is to say, unless something is done, strips of the cylinder amounting in all to about 13½ in. cannot be doffed. The first means adopted to remedy this defect was the giving to the last pair of worker rollers on the cylinder an oscillating motion. Moving transversely on the cylinder, the

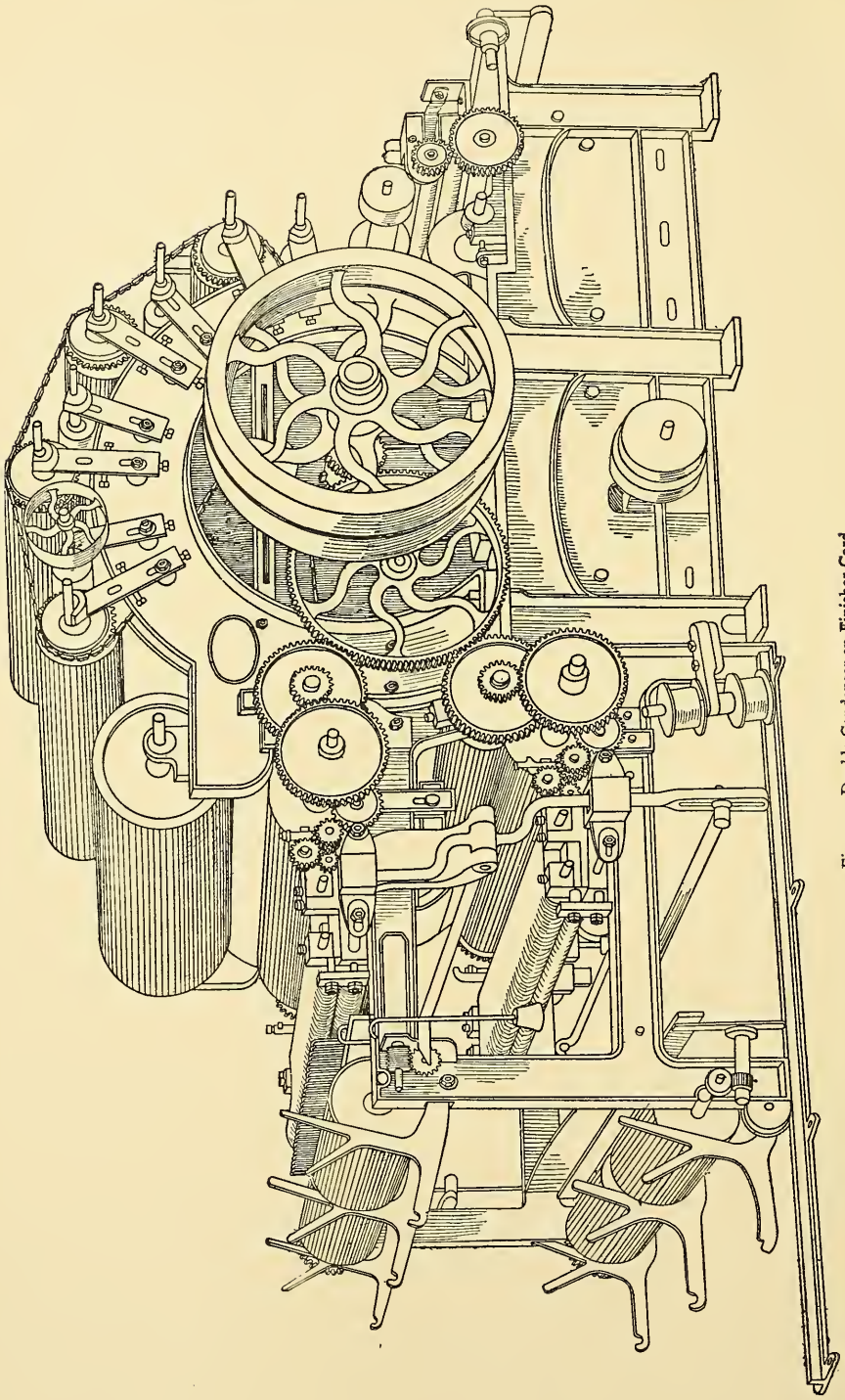


Fig. 75.—Double Condenser on Finisher Card

workers equalize the fibres on the cylinder. The contrivance works fairly well; but, of course, there is always some little trouble arising from the gathering of wool on the cylinder at those points untouched by the doffer rings.

Single Doffer and Double Stripper.—By applying a second stripper to the doffer a double line of slivers is obtained and carried to separate

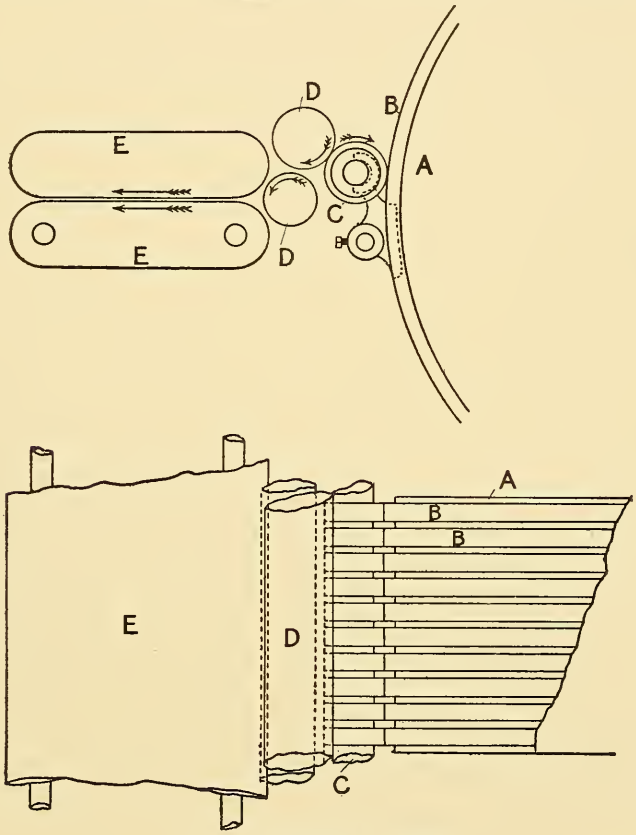


Fig. 76.—Details of Single Condenser

A, Doffer cylinder. B, Ring of eards. C, Stripper roller. D, Delivery rollers. E, Rubbing leathers.

rubber condensers, increasing the productivity of the condensers at small expense. Otherwise we find nothing noteworthy in this form of machine.

Double Doffer and Double Stripper.—Seeking a way of doffing the cylinder clean, an inventor hit upon the idea of putting on two doffer rollers, the one above the other, the rings on the doffer below being placed so as to cover the spaces between the rings on the doffer

above. Following out this plan, a double condenser was made which has been one of the most serviceable machines in the trade (fig. 75). For all practical purposes the double condenser is very good.

Belgian Tape Condenser.—Instead of changing the form of the doffer on the finisher card, M. Bolette, the Belgian inventor, conceived the idea of delivering the wool in a sheet from the carder and dividing it up into parts suitable for condensing by a special apparatus. The doffed sheet is received on the apron beneath the doffing comb and led under the delivering roller. Here are two iron rollers peculiarly

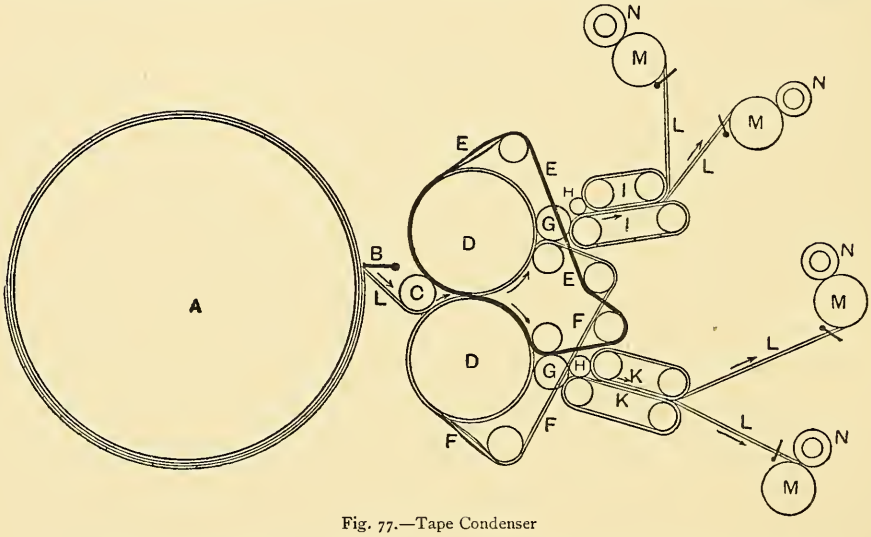


Fig. 77.—Tape Condenser

A, Doffer cylinder. B, Doffer comber C, Guide roller. D, Strap rollers, grooved to receive the straps E and F. G, Stripping discs. H, Guides. I, K, Rubbers. L L, Slivers. M, Drums. N, Bobbins.

constructed and equipped. Grooved rings alternate with spaces of equal breadth on both rollers, the spaces on the one being opposed to the grooves on the other. Two sets of endless belts, held taut and driven by rollers at different points, wind round the rollers and fill up the grooves. Taken together, the two sets of rollers form a continuous surface and thus take on the whole sheet of doffed wool; but the belts cross each other and thus split the sheet of wool into strips the breadth of the belts, which bear the lines of fibre forward to where a wiper sends the material in between the condenser rubbers.

Condensing Rubbers.—By taking a wisp of fibres and rolling it between the palms of the hands, we can condense it into the shape of a thread. This simple fact lies at the basis of the wool condenser. The idea is to bring the strips of fibre under the rubbing action of two

plain surfaces. On the old form of condenser, still doing good work in many factories, the upper worker of the condenser is a set of rollers, clad with leather or some kind of indiarubber composition, given an oscillating and revolving motion, while the lower rubber is an endless band of leather, also revolving in an oscillating manner. The form most commonly accepted, however, is made up of two endless bands of leather stretched on two pairs of rollers, which oscillate and revolve, the one above the other. The rubbers are set close enough to grip the wool firmly between them, and by the rolling, oscillating motion condense the flat ribands into soft, thick threads. Borne forward on the rubbers, but without draft, the threads are wound on large bobbins at the end of the machine.

These rubbers are attached to every condenser, and form an integral part of the machine. The single doffer and stripper has only one pair of rubbers and one delivery. All the other machines described have two sets of rubbers and two deliveries. Few inventions give results so quickly at so small cost. By means of the Belgian tape machine slivers of fine tenuity are obtained. Though almost devoid of tensile strength, the slivers, being firmly compacted, rolled, and felted, constitute a solid basis upon which the woollen spinner can work with freedom, certain of being able to produce from them a good sound thread.

Tow Carding.—Among the other carding engines in use the tow carder stands out with prominent characteristics. Though rejected by the hackler and rougher in the linen and rope factories, tow is not a waste material. Relative to the other fibres, it is short and therefore requires different treatment, but that is all. When both tow and line are made into slivers, the spinner has little to choose between them. Indeed, for fine yarns the higher grades of tow are preferred to the best qualities of line, because the tow is so much more uniform in fineness.

Tow-carding Engines.—For the highest classes of work two carders, the breaker and finisher, are employed; but in the great majority of factories one carding is held to be sufficient. This carding engine is a fine machine, and it possesses structural features special to itself.

Most noteworthy is the position of the feed in relation to the delivery. Instead of being at opposite sides of the machine, the two are at the same end, the feed passing under the delivery. The tow is weighed before feeding. On the feed lattice an area of 36 in. is marked out, and the weight of tow which is to be made into a given

length of sliver is laid evenly within the space. If the attendant has taken pains to spread the fibres evenly, the feed is sufficiently accurate. The feed apron or lattice carries the fibres in under the delivery table to the slowly revolving feed rollers.

The main cylinder, 5 ft. in diameter, clad with rough and strong card clothing, revolves in the direction opposite from the cylinders of other carders, turning in towards the feed. Otherwise delivery on the fore side would be impossible. As the great cylinder comes round on the tow fed, it beats the fibres down with a hard drag and combs them out. Round the greater part of the circumference of the cylinder, workers and strippers alternate, the workers carding off the fibres from the cylinder and the strippers giving back the spoil.

On this machine there are two delivery heads, though some machines have three and often four. The doffer rollers are merely workers, but the stripper tools, instead of lying towards the main cylinder, stand outside and deliver the doffed fibres to a set of calender delivery rollers. By means of the delivery apparatus the doffed sheet is formed into three broad slivers, which are compressed into ribands on the calender rollers. After this the method of delivery depends upon the weight of sliver which is to be made. On this carder, for example, we can lead out into the sliver cans the whole six ribands separately, or we can combine them into one. Guide rollers are set at the end of the carding engine, which impart to the slivers the direction designed.

Dealing with a fibre of such strength, the action of the carding engine is necessarily severe. The workers are crowded on the cylinder, with strippers in between, and no loose or tangled fibre can pass through. When the slivers come through they are smooth, even, and of fine texture.

Jute Carding.—The manufacture of jute is the shortest of textile processes. Excepting the softener, no preparatory machine touches the great fibre before it comes to the carding room. Upon the carder, therefore, many duties are laid which, in other processes of fibre preparation, are undertaken by several sets of workmen and machines. Without entering into comparisons, we specify the several functions of the jute carder. Even after the softener has done its work, and reduced the length of the jute, it is still on the average 6 ft. long. No spinning machine could handle such a length of fibre. To reduce the length of the fibre is one of the first duties of the carding engines. Like all bast fibres, jute is capable of more minute division than the

retting process brings out. The second function of the carder, therefore, is to divide the fibres finely. Thirdly, we find that the mixing has not quite separated those fibres which nature has placed in company, and the ideal mixing is that which breaks up the natural order and unites alien things intimately. This we hope to accomplish on the carding engines. In addition, the fibres must be straightened out, laid in parallel order, and cleared of broken fibres and other rubbish.

To attain these highly important ends, two carding engines are employed, the first being named the *breaker* and the second the *finisher card.*

Jute Breaker Card.—Built to manipulate the largest of textile fibres in general use, the jute carder (fig. 78) is a gigantic machine. Cylinder, rollers, feed lattice, delivery apparatus, and card clothing are alike large, and adjusted to accommodate the great length of fibre to be worked.

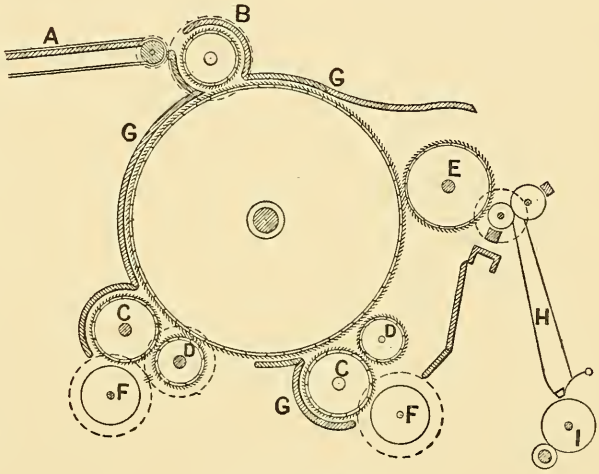


Fig. 78.—Jute Carder

A, Feed lattice. B, Licker-in. C, Stripper rollers. D, Worker rollers. E, Doffer. F, Tin roller guard. G, Plate guards. H, Sliver channel. I, Delivery roller.

Cylinder. — Lifted up from the floor, and supported on strong bearings in a heavy frame, the main cylinder sits almost in the very centre of the carding engine. 4 ft. in diameter, the cylinder is covered closely with strong steel points, slightly inclined in the direction of its revolution, which is towards the front of the carder. The surface speed of this huge roller, when in full working flight, is 2000 ft. per minute.

Workers and Strippers.—Only two sets of workers and strippers operate upon the great cylinder of the jute breaker. Another point worth noting is the relative sizes of the pairs of rollers. In almost all other carding engines the worker is larger than the stripper, but here the proportions are reversed. The stripper is 13 in. in diameter and the worker 9 in. A peculiarity is also observable in the setting and positions of the pairs. We have accustomed ourselves to thinking

of strippers and workers revolving like little parasites on the heads or upper circumferences of main cylinders, but these jute rollers are placed on the under side of the cylinder, the one pair directly under the axle and the other on the lower curve at the back. The worker rollers have long and strongly curved teeth, inclined opposite to the direction of their revolution; the surface speed of the rollers is 50 ft. per minute. Equipped with teeth almost identical in form with those of the main cylinder, the large strippers attain a speed of 450 ft. per minute.

Doffer.—Set high up on the back of the main cylinder and almost touching it, the doffer roller is covered with fine teeth closely set in opposition to the direction of its revolution, which is at the rate of 150 ft. per minute. Behind the doffer a stripper roller works in conjunction with a larger roller placed over it. From these a flat and converging channel slants down to the delivery calender rollers. On the fore end of the machine a feed lattice slanting upwards and a licker-in roller, clothed with teeth, complete the working equipment of the jute carder.

Guards.—Before examining the methods of working the large machine, there are some special features which should be observed. Under and over the licker-in, round the front of the main cylinder at top and bottom, under the strippers and behind the doffer roller, casings of strong tin are extended, and behind the pairs of strippers and workers tin rollers are placed. With a long fibre like jute, the points on cylinder and rollers are apt to leave flying ends, and the tin plates and tin rollers have been put on to keep the fibres within the machine. Other features in the carder have been devised to accommodate the size of the fibre. By slanting the feed lattice the jute is presented to the licker-in at such an angle that it bends the fibres gradually. Similarly, a long inclination is allowed between the licker-in and the main cylinder. Otherwise the tremendous downward stroke of the mighty swift would break the fibres to fragments. The long, slanting channel, which receives the doffed sheet of fibres and gradually compresses it to a narrow band for the calender delivery rollers, has also been designed to protect the long fibres.

Operations.—Weighed and spread evenly on the feed lattice, the jute is drawn within touch of the licker-in, which bears it forward to the main cylinder. With a quick downward stroke the great cylinder whips the fibres round itself and drags them off, elongating the lap fed a thousand times. With opposed teeth, the worker revolving

on the under side of the cylinder arrests the fibres, pulling and finely dividing them, while clothing itself with them. At the same moment the stripper follows at quicker speed and unhooks the fibres from the teeth of the worker. The main cylinder recovers the jute from the stripper, because its speed is so much greater and the teeth of both are inclined in the same direction. The worker and stripper further round the main cylinder go through the same motions, dragging and returning the fibres with combing teeth.

The worker is placed behind the stripper on carding engines employed on large fibres, the object being to repeat the carding till the fibres are so evenly disposed as to pass the worker. On the jute carder the device is more than ordinarily effective, the length and thickness of the fibres making passage of the worker a matter of some difficulty. But for the great weight of the main cylinder the amount of carding done in a day on a jute carder would be small.

By the time the jute comes round to the doffer it lies fairly straight, and is even somewhat deeply embedded in the teeth of the cylinder. Hence it is that the doffer is placed very near to the main cylinder. The opposed teeth of the doffer pull the jute from the cylinder, and the stripper rollers take it off the doffer roller and send it down the broad channel in a sheet. As it extends downwards the channel narrows in size, compressing the sheet of fibres to its own breadth. A ribbon of about 4 in. broad, the jute issues on to the delivering rollers, which convey it to the cans placed ready to receive it.

On the jute breaker card the question of draft is of critical importance. For the first time we have the opportunity of applying measure to the fibres. On to the 36 in. of space marked on the feed lattice we have laid 6 lb. of jute, or 2 lb. to the yard. By making the delivery rollers attain a surface speed fourteen times quicker than the feed, we obtain a sliver weighing 7 yd. to the pound.

Jute Finisher Card. — The slivers from the breaker card are taken in cans to the feed board of the finisher card, and ranged in a group of twelve. Thus arranged, the slivers form a solid sheet, and the fibres are drawn in by the feed roller and licker-in, to be carded once again. The mixing performed by this operation tends greatly to produce a uniform blend. Clothed with finer teeth, more closely set, and additional workers and strippers, the finisher carding engine further reduces the length of the jute and still more finely splits the fibres. When it comes off the finisher card, the jute sliver is a fine, smooth, thick rope, uniform in texture and lustrous in colour.

Other Carders.—The carding engine has been utilized in various ways by many of the minor branches of the textile industry. Waste silk, ramie, hemp, and other fibres are opened out, smoothed, laid parallel, mixed, and at last converted into the sliver which is the almost universal beginning of yarn spinning. Composite and mobile in structure, the range of the carding engine is very wide. Card clothing so fine as to draw and gently treat the filmiest of filaments, or coarse and long enough to tease out the heaviest and strongest of textile fibres, is placed at the service of the manufacturer. If required, the main cylinders, flying at the rate of 2000 ft. per minute, will carry through any kind of material against the severest workers; lowered in speed to 500 ft. per minute, the great rollers softly play on the weakest shoddy. Workers, strippers, and doffers can be set so close to the main cylinder that not a flying hair escapes them, or so widely that the curliest of fibres are gently combed. There are limits to the usefulness of the carding engine, of course, but it is safe to say that if no other instrument for combing out fibres were available, the carder could be adapted to perform every service with high efficiency.

Waste Silk and Ramie Carder.—Being comparatively new fibres, waste silk and ramie have been generally worked on the machines already in existence, employed either for cotton or wool; but the practice has hardly been fair to the new fibres. Recognizing this, machinists have sought to provide special tools for them. One of these is a carding engine which is an interesting combination of appliances. The prepared fibres of waste silk or ramie are laid on an endless feed band in front of the machine and carried up to a pair of fluted feed rollers. Drawn on by the rollers, the silk passes in between a pair of endless bands, tooth-covered, and revolving close to each other. The carding teeth of the bands are set so that the contained fibres are slowly borne to the inner end, where the bands turn close to a large carding cylinder. With its teeth the cylinder strips the fibres from the revolving bands and carries them off. Two pairs of workers and strippers revolve in close proximity to the cylinder, which has but loosely grasped the silk. Between them, the workers and strippers comb out, mix, and straighten the silk on the cylinder. The doffing apparatus lifts the finely carded material off in the form of a filmy sheet, and forms it into a flat sliver.

CHAPTER VII

Gilling

Gilling. — The carding engine is the most perfect mechanical embodiment of the combing principle we possess; but it sometimes happens that cruder appliances, which are nearer to handicraft, serve delicate and special purposes better than the more highly developed machine. The *gill box* is an instance. Viewed as a mechanical contrivance the gill box is not a masterly achievement, but it produces good work on materials with which the carding engine, as it is constructed, cannot effectively deal, and brings to finer condition some of the products of the carder itself.

The term gill is a corruption of the French word *aiguille*, signifying *needle*. No doubt the original gilling machines were brought over from France by the Huguenots in the seventeenth century, and a mispronunciation of the French word became the English name of the machine. Gilling is literally "needling", the main tools of the gill box being combs formed of needles stuck point upwards in wood bars, or screwed into metal rods; for the gilling operation consists in the straight, even, regular combing out of fibres in a horizontal line. The unbroken and uniform length of many fibres constitutes their distinguishing and most valuable quality. Mohair, alpaca, Lincoln and Leicester wools, and most of the bast fibres are valued for their length, and hence the desire to preserve it unbroken throughout the preparatory process.

Another factor must also be taken into account. Woollen threads alone can be made up of crossed and felted fibres. To make any other form of yarn the fibres must be straight and parallel. Cotton and very short fibres can be laid in parallel lines on the carding engine, but long fibres do not come out in that condition. Hence it is that long fibres outside the scope of the carder, and medium fibres partially prepared on the carder, requiring to be laid in parallel condition, are alike passed through the gilling machine. As we have seen, much of the rough preparation of wools is done on the carder, but gilling and combing come after, if the material is to be made into worsted yarn.

The Gilling Machine. — Forming the heart of many kinds of machines, the gilling apparatus is fundamentally nothing more than a series of spikes set point upwards in a horizontal position, geared to travel in a horizontal direction between feed and delivery rollers;

but the sizes and arrangements of the spikes or needles are conditioned by the kind and class of fibres operated upon and the purpose for which the product is destined. Gills are of two classes, the *sheet gills* and the *faller gills*; the latter being specially favoured by cloth manufacturers, while the sheet gills, once largely employed, are now to be seen chiefly in the rope factory.

The faller or screw gills are horizontal bars studded with spikes more or less closely set, and made to travel forward on a pair of screw shafts. At the ends of the screws an eccentric cam knocks the bars down, and they are received by another pair of screw shafts which bring them back to the point of starting, where the bars are lifted up again on to the working level. The gill bars thus exercise a combing function upon whatever fibres may be fed to them on the upper level.

Sheet gills are differently constructed. The bars, bearing the spikes, are chained together in an endless band, which is stretched between two rollers. A continuous succession of serried spikes are carried across the machine, within which the sheet gills are set, drawing and combing out the fibres.

Gilling is a stage in the manufacture of worsted, linen, jute, and hemp yarns, and in each the apparatus works under different conditions. To avoid repetition, we have grouped every branch of textile manufacture interested round the machine. At the same time, however, in order that those desirous of pursuing the study of only one industry may be satisfied, the special features of every branch are so clearly defined as to afford continuous instruction, passing on from stage to stage as if the work had been written for that one industry alone. In this chapter the industries are grouped round the gilling machine as follows: 1, worsted; 2, flax; 3, jute; 4, hemp.

Worsted Thread. — The gilling machine marks the difference between a woollen and a worsted thread. In former days wools were classed as combing and carding; but that mode of classification is almost obsolete. Some of the long wools, it is true, can never be worked on the carding engine; but many of the finest worsted wools and all the commoner kinds are prepared on the carder first. Compared with the great mass of fibres the worsted worker receives from the carder, the amount taken direct from the preparing room is very small. Therefore, as we have said, the point of difference between woollen and worsted manufacture is the condenser on the one hand and the gill box on the other.

Worsted threads are divided into three large classes—*cloth*, *carpet*, and *knitting yarns*. The first class includes the long-wool yarns, the material of which is passed directly from the opener to the gilling machines. The second class, on the other hand, includes so-called worsted yarns which are sent from the carding to the spinning. The same may be said of a portion of the last class. It is necessary to remember and note these variations; otherwise, when they are met in the spinning department, some confusion is sure to arise.

The distinguishing mark of the worsted thread, and the mark which cannot be mistaken, is the straightness and parallel order of all the fibres in the thread or yarn. In a typical worsted thread all the fibres lie in one direction, and the outlines of it are clear and definite. In a worsted cloth every thread is a line; the threads of a woollen cloth, on the contrary, may be indistinguishable.

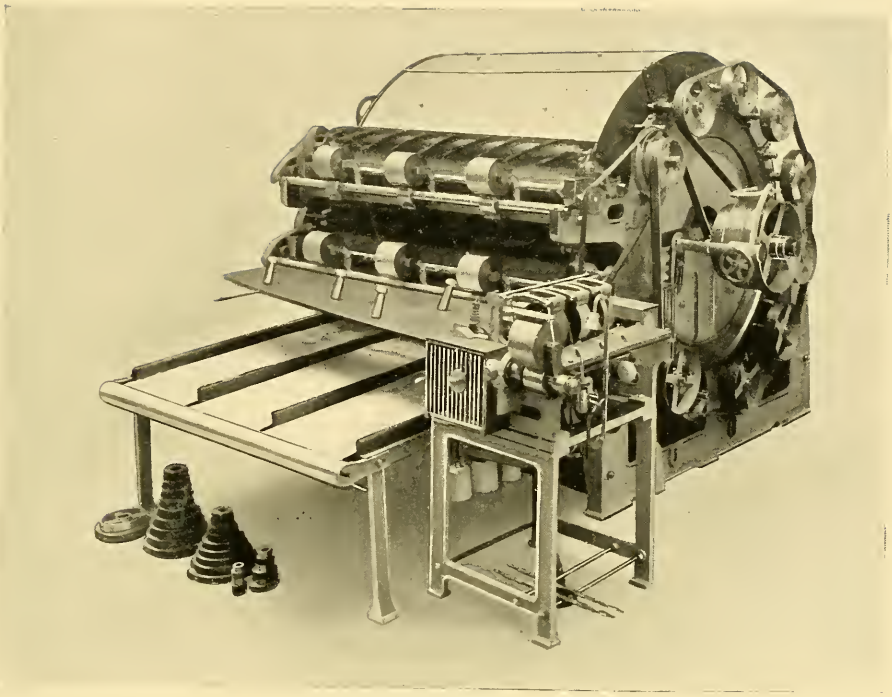
Backwashing.—The favourite method of delivery for worsted from the carding engine is Tatham's patent balling machine already described. The slight twist given to the sliver, harmful if it is to be used for woollen manufacture, serves a good purpose here. For the wool must be thoroughly purified from oil before being sent through the combing machines, and the dirt and grease the wool has taken on in the passage through the carder also require to be removed. Backwashing may either be done on a special and separate machine or on one attached to the first gill box. It need hardly be said that the separate machine is more thorough, but the smaller machine may serve well enough. The large backwasher has four pairs of squeezing rollers and two bowls, and a set of copper drying cylinders charged with steam. From the large bobbin on which it has been wound the sliver is led into the first bowl, which is charged with soapy suds. The squeezing rollers in the bowl give the sliver what is called the wet nip. Another pair of squeezing rollers above the bowl give it a second pressing and send it on to the next bowl, in which it is similarly treated. The fourth pair of squeezing rollers press the scour out of the wool, and it then goes along to the drying rollers or cylinders. Some machines have plain steam-heated cylinders, but the finest invention we have seen is a large frame, holding out a series of copper cylinders driven by a central pinion wheel. The steam comes up through the frame at the side, and the cylinders are all driven at one regular speed. Led in a winding course through and over the cylinders, the sliver is well dried and passed on in an even condition, at a regulated speed, to the gill box.

Worsted Gilling.—The principle of the worsted-gilling operation is simple, on the face of it. A pair of fluted rollers feed the wool, or slivers, while retaining a firm grip on the fibres. A set of faller gills, with their rows of spikes, run on screws and draw away the wool with a combing motion. At the end of the screws the gills fall down and leave the wool in the possession of the fluted delivering rollers, which have a speed four times, six times, or eight times the speed of the feed rollers, and therefore draw out the fibres to that extent, delivering them to the balling or lap-forming apparatus, whichever may be employed.

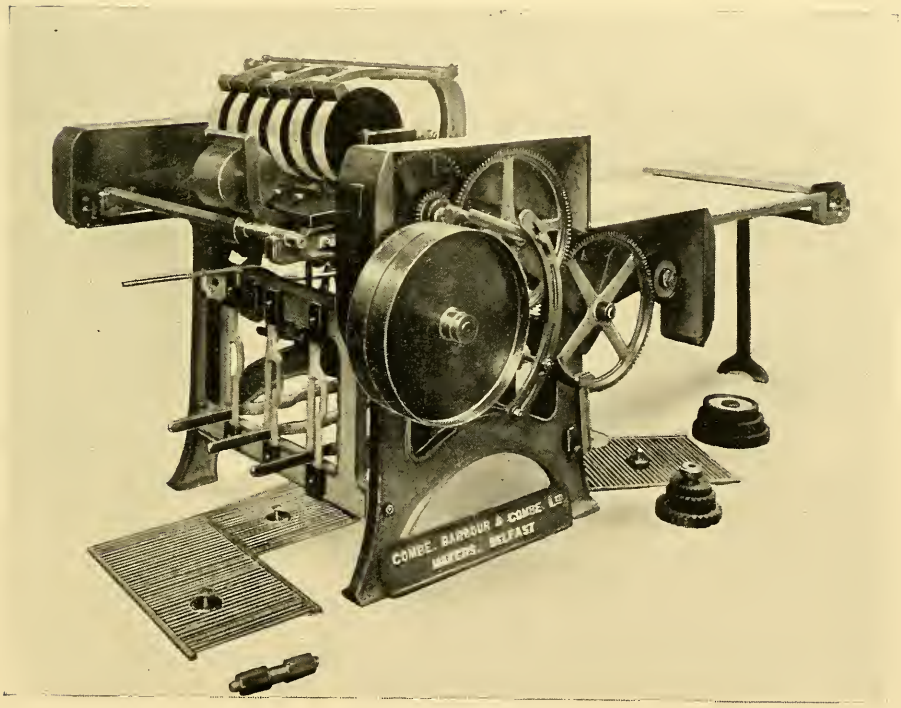
The simplicity of the gill box has been abolished in the effort after speed and efficiency. The fluted feed and delivering rollers are given a measured degree of pressure according to the amount of "nip" designed, by pressure of vertical screws. The horizontal screws on which the faller gills are run have been modified in various cunning ways. The pitch of the screws bringing back the fallers to the point of departure is made coarser, to allow more fallers always to be on the upper set. Again, the carrying screws are divided into two or more sections, each successive section being finer in the pitch than the one preceding, so that the fallers on the second set will move more quickly than those on the first, and those on the third run more quickly than the second set of fallers, gaining draft in the course of the one machine.

It is generally admitted that the use of two sets of fallers, at least, is advisable on the first gill box, because by that means the draft on the fibres is graduated from one end of the machine to the other, enabling the draft to be greatly increased while lessening the chances of broken wool. The first of the faller gills may be given a speed a very little greater than the rate at which the wool is fed, while the second set may attain a speed approximating to that of the delivering rollers. In this way the chances of nipping fibres are minimized. Sometimes fluted rollers are set between the pairs of screws to guide the wool and add to the draft. A draft of twelve is obtained on these gill boxes.

A complete set of preparing boxes contains six machines, all having the same effect on the wool; but the third gill box changes the method of delivery. Instead of a broad lap, the machine delivers a broad ribbon or sliver, which is coiled into cans placed in position to receive it. Half a dozen of these cans are placed before the fourth gill box and the slivers led into it. The slivers are drawn into one,



TOW CARDING ENGINE



FLAX SPREADBOARD

(Combe, Barbour, & Combe, Ltd., Belfast)

but that one is thinner than any of the ends of which it has been composed. Suppose, for example, six slivers have been fed into the gill-box, and that the draft is nine, then the six slivers are drawn into one a ninth of the bulk of the whole lot, or to six-ninths of a single one. The operation of combining the slivers is repeated on the fifth and sixth boxes, bringing the whole of the wool being gilled to uniformity.

Another name for gilling is preparing, and the word exactly describes the function of the gill boxes. In preparation for the combing machines, which finally straighten out and sift them, the wool fibres are drawn and given a parallel direction by the needle-like spikes of the faller gills.

The Flax Spreadboard.—No gilling machine has a more important function to perform than the spreadboard of the linen industry. It is the one sliver-maker in flax manufacture. After the hacklers and dressers have done their work, the flax remains a bundle of disconnected fibres. To bring the fibres into such unity as to supply the spinner with a basis to work on, is the function of the spreadboard. The largest and most elaborate of faller-gill machines, the spreadboard requires detailed examination. In front is the marked feed board, with travelling apron. The sizes of the marked spaces on the board are graded, a given weight of flax being spread over a given space, according to the weight of sliver designed. At the edge of the feed band a set of vertical steel plates act as guides to the fibres on the way to the feed rollers. The guides or conductors are necessary. The feeder lays the stricks of flax in lines, not in a level sheet, each strick, root end first, lying well over the one before it. Without the conductor plates the long fibres might easily be deflected from the straight course.

The lower feed roller is fluted and the upper one is covered with leather, so that the grip of the feed may be sure but soft. Beyond the feed rollers we find the faller gills, mounted on the travelling screws. The motion of the gill bars is simple, the screws carrying them to the end of their course and letting them drop on to the returning screws below; but the bars themselves are set in a way which has an important bearing on the work of the machine. The gilling needles are not set in a continuous row along the bars. As a matter of fact we must think of them in a different way. The combs of the gill bars are separate entities. We may fix on to the bar a set of coarse combs with thick spikes and place them so far apart that three occupy the whole breadth; or we may use fine combs

and set them so close as to place six on the bar. Each line of fibres fed has its own set of combs, following one after the other. This serves to explain the conductors, and the operations which follow carry out the plan. When the combing bar drops down, it has brought the flax fibres within the sphere of the drawing rollers, across the brass guide plates. The under roller of the drawing pair, the boss as it is called, is plain and made of iron; the upper or presser roller, made of wood and of wide diameter, is weighed down by heavy blocks of metal modified by springs. When passed in between the boss and the presser rollers, the flax comes out in the form of a flat ribbon.

At the back of the drawing rollers a plate, having as many diagonal slits as there are "heads" on the machine, receives the pressed ribbons. The diagonal form of the slits gives a slanting direction to the ribbons and causes them to converge readily on the delivery rollers, which convert them into a single sliver and drop them into the can waiting at the end of the machine.

The upper roller of the delivery pair has not a motion of its own, being merely a weight and regulator. The under roller has not only a drive, but it also acts as the measurer of the length of the sliver. On the end of the shaft a small worm is set which gears into a wheel; this wheel acts on another, named the "bell" wheel, one revolution of which rings a bell. By varying the relations of the train of wheels and the worm the length of the sliver to be paid into one can may be increased or lessened. At the warning of the bell the attendant removes the full can and places an empty one.

Jute Gilling.—From one point of view the gilling operations in jute manufacture might properly be included in the spinning department. Technically the process is designated drawing, and that would seem to be conclusive. On the other hand, however, the action is a purely combing and straightening operation, the sliver being delivered as well as received. No more typical gilling operation is practised anywhere; the jute-gilling machine might be taken as the standard from which all others are variations.

As we have seen, the carding engine is the only jute-preparing machine; the burden of the whole labour of making the great fibre into a coherent sliver lies upon it. If, therefore, the fibres are not all perfectly straight and parallel, little can be said; the wisest course is to supplement the efforts of the carder. This is primarily the function of the gilling machine.

The first *drawing frame*, as the gilling machine is called in the jute trade, is usually a double carriage; but the two sides of the frame are alike, and what is said of the one may be applied to the other. On the fore end of the machine (fig. 79) the guide plate leads up to the feed rollers, of which there are three. Designated retaining rollers,

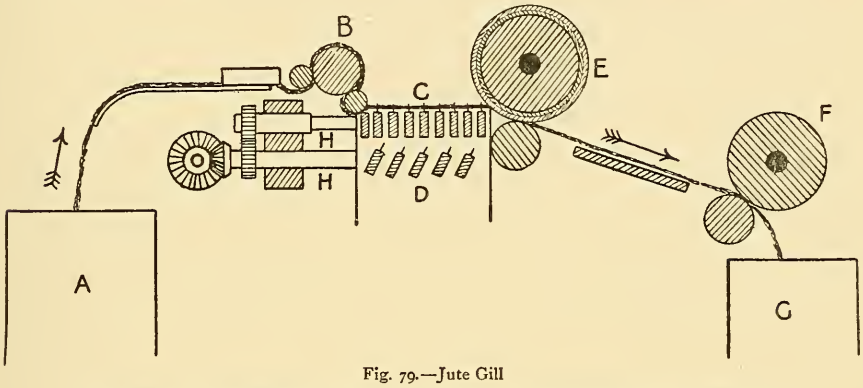


Fig. 79.—Jute Gill

A, Jute can. B, Retaining roller. C, Upper row of gills. D, Returning gills. E, Back rollers. F, Calender rollers. G, Drawing can. H H, Faller screw.

these pay out the long fibres in a steady manner. From the sliver cans placed in front, the doubled sliver is passed under the first roller, over the second, and under the third, and held forward to the gill pins as the faller comes up. One has only to remember the length of the jute fibre to understand the peculiarity of the feeding apparatus. The carding engine has reduced the length of the fibres to about

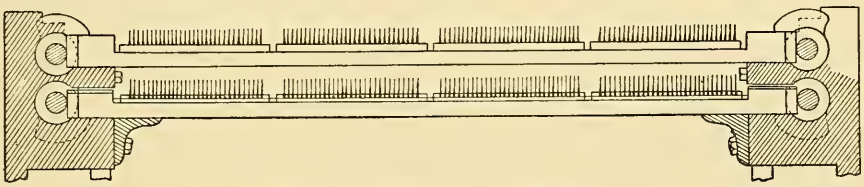


Fig. 80.—Front View of a Set of Faller Gills

8 or 9 in.; but even that reduction does not altogether obviate the difficulty. Fed in with a single fluted roller, the jute would either be drawn irregularly out of its hold or cut through by the force necessary to retain it. The three rollers hold and give out the jute steadily to the drawing combs on the faller bars.

There are four gilling combs on each horizontal bar (fig. 80). As it is lifted up from the lower screw to the level of the upper screw, the combs of the bar insert themselves into the fibres offered by the

feed rollers and run off, borne by the resistless force of the turning screw, drawing out and carrying away what fibres the combs have caught. At the end of its traverse, the bar drops down on to the screw shafts beneath, leaving the fibres it has borne in the grip of the drawing rollers.

3 ft. long, the travelling bars (fig. 81) have bevelled ends which fit into the thread of the screws, and steel slides the length of the screws carry the bars steadily to the end of their traverse. The

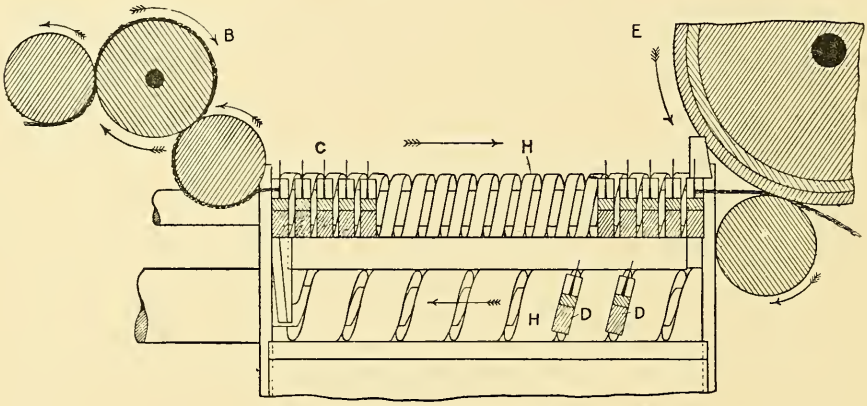


Fig. 81.—Detail of Jute Gill (see fig. 77)

B, Retaining roller. C, Upper row of gills. D D, Returning gills. E, Back rollers. H H, Faller screw.

pitch of the upper screw is 1½ in., the lower screws being rather coarser in pitch.

The four gills are separate, and each one bears along its own burden of doubled sliver to the guide plate. All four slivers may be passed simultaneously and individually through under the heavy presser roller which rests upon the delivery rollers; but it is usual to form the guide plate so that it brings two of the slivers together, and only one pair of slivers are taken by the coiling rollers into the cans.

Hemp Gilling.—The hemp fibres used in this country are generally rope fibres, and therefore need no delicacy of treatment. For rapidity and thoroughness no gilling machine equals the sheet gills. The screw gill (fig. 82), as constructed at the present day, is a much finer tool; but there is no reason why the sheet gill cannot be made as fine if need be.

Sheet Gills.—In essential nature the sheet gill is nothing more than the faller gills made horizontal and continuous. The sheet is

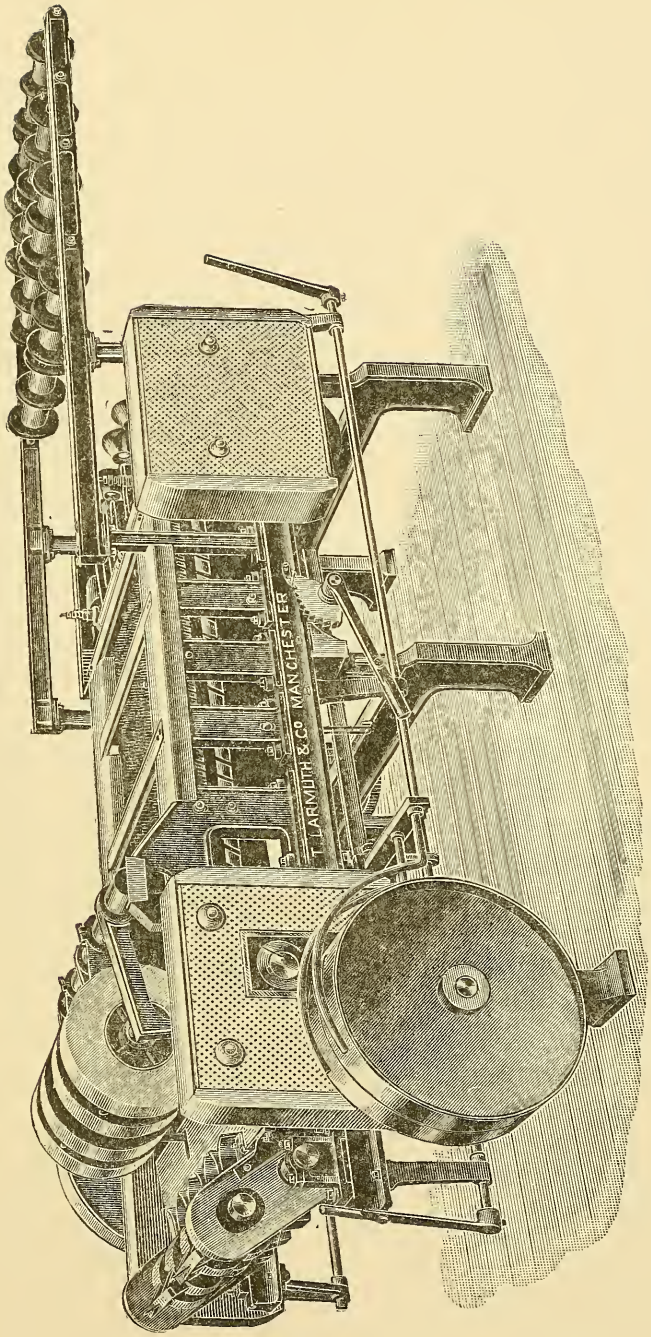


Fig. 82.—Heavy Screw Gill Drawing Frame

simply a series of gill bars strung together on an endless chain and stretched between rollers fitted with pinions to carry them round. We have the feed rollers before and the delivery rollers after, as on the screw gills. Instead of coming back to the point of starting by means of a returning screw, the gills on the sheet are carried on an endless chain both on the working and the lower level. Projected from the feed, the hemp fibres are seized by the row of gill points coming up round the roller; the gill bar bears the hemp forward, and another bar follows in train. Thus, in procession, the drawing, combing gills accomplish the traverse, and then, as each bar drops round the end roller, the fibres are left in the grip of the drawing rollers and pulled onward to the pressing and delivering rollers, to be formed into a sliver or set of slivers. The operation is rapid and direct, transforming the masses of fibres in a few moments into straight and regular slivers.

Double Sheet Gills.—A refinement of the gilling process, which has much to commend it, was introduced by a believer in the possibilities of hemp as a fibre. Two sheets of gill bars are stretched on the machine. The first has open and large points, and revolves at a moderate rate of speed; the second sheet holds finer spikes, more closely set, and revolves at much higher speed, varying from four times to six times quicker than the first. The effect of the double sheet is twofold; it divides the fibres more keenly and draws them out to greater length.

Further Treatment of Hemp.—When it comes off the first gilling machine, the hemp is simply coiled on the floor, being a large and heavy fibre. It is only when the hemp has passed into the drawing machines that sliver cans are required. As this belongs to the spinning department, we leave them meanwhile.

Gilling Draft.—Simple as the gilling machines are, taken as a class, the draft problems which they bring are not to be solved without some consideration. Feed and delivery speeds give the total amount of draft, it is true, but we need to know something more. It is important that the draft of the gills should be exactly known. As illustrative of the whole question, and to afford a comprehensive guide to the subject, we take the detailed study of the worsted-gilling draft given by a writer in a well-known textile periodical:—

"As in all other machines, the calculation of the relative rates of speed of the various parts of the machine must be dependent upon first determining which of the wheels are driving and which are

driven. That being done, the whole operation is quite easy, for each set must be multiplied together separately and one divided by the other. The quotient is the relative speed of the first and last wheel respectively. Take the particulars of a gill box, and find which are driving and which are driven wheels. First there are two back shafts, the lower one receiving power from the main driving shaft, and which is consequently a driven one. This carries the wheel which communicates motion to the back rollers and to the upper back shaft, so that the wheels upon the lower shaft are drivers, and those upon the back rollers and upper shaft receiving power are driven ones. The upper back shaft now communicates motion to the screws by means of bevelled wheels, so that those upon the shaft are drivers and those upon the screws are driven; and it also communicates motion to the front rollers by a series of intermediate wheels. Now let the following represent the train of wheels between the first driver and the last driven. Say the drivers are 20, 24, 27, and 72 respectively, and the first driven are 75 each and the last 29. That is, the wheels have those numbers of teeth each. Then, to find the draft, if the three driven are multiplied together for a dividend and the three drivers for a divisor, the draft will be found at once, thus:

$$\frac{75 \times 75 \times 75 \times 29}{20 \times 24 \times 27 \times 72} = \frac{90625}{6912} = 13.1.$$

"But the diameter of the rollers must be taken into account also, and of course as one or the other is increased or decreased, the draft would be altered; or if any change takes place in one of the wheels of the train, either the drivers or the driven, a corresponding change takes place.

"In finding the draft between the fallers and the back rollers the speed and pitch of the screw have to be taken into account, and the wheels driving the front roller left out of consideration. Thus, let the bevelled wheel driving the screw have twenty teeth, whilst that upon the screw itself has twenty-four teeth, and the pitch of the screw is, say, 1¼ in., then to find the number of fallers which will rise for one revolution of the back roller, it will be:

$$\frac{75 \times 75 \times 75 \times 20 \times 1.25}{20 \times 24 \times 27 \times 24} = \frac{19531}{576} = 33.9 \text{ in.}$$

the distance the fallers travel for one revolution of the front rollers;

and if this be divided by the circumference of the front roller in inches, the draft is obtained at once.

"There is now to consider the draft between the front rollers and the fallers, and the different methods of arriving at it. Taking the dimensions given above as showing the distance fallers travel for one revolution of the front roller, and dividing that by the circumference of the front roller, the draft between the fallers and the back rollers is obtained. Thus it is shown that the distance travelled by the fallers for one revolution of the front roller is 33.9 in. Now, suppose the diameter of the front roller is 9 in., then 33.9 divided by 9 equals 3.766, which is the draft between the fallers and the back rollers. As for the draft between the front rollers and the fallers, there are several methods of ascertaining what it is. For instance, if the draft of the whole box be divided by the draft between the fallers and back rollers, the result must be the draft between front rollers and fallers. Thus, the draft of the whole box is shown to be 13.1, and that between the back roller and fallers is 3.766. Then $13.1 \div 3.766 = 3.48$ nearly; or, in other words, 1 ft. taken in at the back rollers is drawn out by the fallers to 3.766 ft., and each foot of this is again drawn by the front rollers to 3.48 ft., so that the whole of the drawing which takes place is equal to 3.766 by the fallers, and 3.48 by the front roller, and $3.766 \times 3.48 = 13.1$, the total draft.

"Another method is to take the whole draft of the box and multiply it by the circumference of the front roller for a numerator, and use the number of inches the fallers travel for one revolution of the back roller as a denominator, thus:

$$\frac{13.1 \times 9}{33.9} = 3.48,$$

giving, of course, just the same result as before."

Another method is to take the wheels which communicate power to the front roller, and the circumference of that roller, into account, along with those which drive the screw, and the pitch of the screw, taking the drivers and driven respectively as before, thus:

$$\frac{24 \times 29 \times 9}{20 \times 72 \times 1.25} = 3.48$$

So that, no matter how it is taken, the result will come out the same.

Having grasped the principle which has been illustrated at such length, it is open to anyone to effect changes upon the gill box employed in respect to speed of fallers and amount of draft on any part of the machine, by changing the wheels of the driver or the driven, or by altering the pitch of the screws.

CHAPTER VIII

Combing

Combing.—Uniformity in length of the component fibres is the prime condition of a perfectly even thread. Good yarn cannot be produced from fibres differing widely in length. It may be asked why the selection of short fibres from long is not made a special aim in the mechanical formation of the sliver. The reason is very simple and purely economic. Nothing would give the yarn manufacturer greater pleasure than to produce perfect threads; but the consumer must recoup him for his expenditure on the product, and that is what he finds very few people willing to do. The manufacturer buys wool or cotton containing fibres of varying length; his interest is to utilize every ounce of the material; therefore he seeks machinery which produces the largest possible amount of yarn of a given class from fibres of mixed lengths. It is only in branches of the textile industry which command a high level of prices that we find a method of production which involves selection of the long and rejection of the short fibres. The silk industry and the highest branches of cotton and worsted manufactures make provision for securing uniformity of length in the fibres which constitute the yarns. Combing is the only method by which that end can be attained so far as we know. By means of the carder it is possible to carry mixed fibres through and obtain the largest possible amount of yarn from a given quantity of raw material. The object of the carder is to utilize everything, and the worth of the carding engine is ultimately determined by the relatively small amount of waste it gives off. The action of the comber, however, is selective. A certain length of fibre will pass, but all below that goes out. Such is the force of economic law, or, in other words, the desire for gain, that the makers of combing machines advertise it as a merit that their comber will utilize a certain very small length of fibre and yet

produce the appearance of a uniform sliver. Of course the combing machines lay the fibres very smoothly parallel; but it seems to be forgotten by many persons who ought to remember that those are qualities secondary and consequent upon good combing, and not at all the primary effects. The aim of combing is to throw out all split, nepped, broken, and wiry fibres. That accomplished, the sliver will lie smooth and even; but it is no triumph to retain as much of the rubbish as possible, and smooth it down by rigorous application of the combs.

Hand Combing.—The basis of the combing operation is contained in the old handicraft. Two long-toothed combs, with handles fixed at the bases of the teeth, were the sole tools. Heated to a temperature high enough to warm, yet not hot enough to sear, one of the combs is made fast to a post. Having given the wool a touch of oil, the comber lashes it firmly into the teeth of the fixed comb, drawing the fibres through the teeth, making the ends even, and opening the wool out. When he has got a mass of fibres stuck in the fixed comb the worker warms his second comb and begins to work the wool between the two, but always pulling the fibres longer and longer. When he thinks he has got all the short fibres well in the teeth of the fixed comb, the wool comber gradually draws away the combed-out long fibres, forming them into a soft, thick rope, modernly named a sliver, leaving the short fibres as noil.

Observe that the success of the hand comber chiefly consists in the removal of short fibres from the wool which is to be spun. He fails if the "top" is found to be mingled with short wool. The spinners for whom the hand comber laboured did not feel the pressure of economic tendency so strongly as the pressure of moral necessity. The object of combing, therefore, is threefold: 1, the opening out and straightening of the fibres; 2, the separation of the short from the long; 3, the formation of a smooth and uniform sliver.

Development of the Machine Comber.—Between the years 1790 and 1792 Rev. Dr. Cartwright, the inventor of the power loom, seems to have laboured at producing a mechanical comber. Though not a success, the contrivance showed the marvellous grasp this clergyman had of mechanical principles. On a table placed in position a number of sliver cans were set, and from them a combined sliver formed in an oscillating frame was lashed into the teeth of a circular comb revolving horizontally, its teeth pointing in to the centre. Over this comb another comb worked, combing out the fibres held in the teeth of the horizontal

comb, drawing away the short fibres. Drawing-off rollers carried off the combed wool in the form of a sliver, and delivered it through delivery rollers into a sliver can. Cartwright's invention did not succeed, and it does not appear that a practicable machine comber came into the world till 1827, when Platt and Collier patented their invention.

Platt and Collier's Comber. — Two circular combs, equal in size, set at angles with each other on a horizontal plane, form the centre of this comber, and both combs are furnished with drawing-off rollers. While the wool is being fed to one of the circular combs the drawing rollers are put out of gear. The wool having been fed by hand into the teeth of one circle, the combs are set in motion. At the first the two combs are so far apart that the teeth of the empty comb barely touch the ends of the fibres sticking out from the other; but they revolve slowly towards each other, and the empty comb fills itself at the expense of its neighbour, combing out the wool. When the pair of circles have accomplished the whole of their traverse the direction of their revolution is reversed, and the drawing rollers are brought up into position on the outside of both. The rollers grip the wool by the ends which have already been combed, and thus comb the other ends. From the drawing rollers the delivery rollers convey the sliver to the can. An improved model of this machine is still in use.

Heilmann's Machine. — While English inventors were labouring to perfect the circular comb, a Frenchman, named Josué Heilmann, devised a combing machine worked on a different principle, which, for a time at least, completely eclipsed all others. Heilmann took out his English patent in 1846, but did not bring the machine over the Channel till three years later. The ingenious Frenchman's idea was to use a cylinder divided into four sections, two clothed with combing teeth and two sides plain, in conjunction with movable nippers and drawing rollers, for alternate combing and drawing of the fibres contained in the machine. The drawing rollers have a swing movement, shifting from one position to another, bearing the wool with them, and so presenting it in a manner suitable for completing the combing. The parts of the machine work as follows. The prepared wool is fed in through the end of a pair of nippers held in the framing of the machine. While the sliver passes in the jaws of the nippers are open, and they close, checking the supply and holding that which has been fed with firm grip. From the jaws of the nippers a tuft of wool projects, and as the cylinder revolves the toothed section gives the tuft a combing, elongat-

ing and straightening and directing the ends in between the rollers which are standing in the first position. The solid part of the cylinder comes round and pushes the rollers, sending them swinging back, carrying off the tuft of wool. At the same moment the nippers open, pressing the small comb within their jaws, thus again combing the wool. In the new position the drawing rollers are brought into contact with the combing side of the cylinder, this time presenting the other end of the woolly tuft to the spikes. Following up, the plain part of the cylinder pushes on the drawing rollers, which, being at the end of their tether, so to say, revolve with the friction, drawing the wool inwards and on to the delivering rollers, by which the wool, joined on to other tufts, is sent out in the form of a sliver. At the other side a doffing roller and brush clear the noils from the cylinder and send them out as sliver.

Then began one of those struggles between rival inventors very puzzling to the common mind. In 1851 Messrs. Donisthorpe & Lister, of Manningham, after years of heavy labour, at last brought out a patent for a combing machine, now known in the trade as the *nip comber*, and to be hereafter described, which bore all the marks of genuine and consistent effort; but the nipping and combing actions were the same as those of Heilmann's machine. A lawsuit was raised by the English holders of Heilmann's rights, and Lister compromised the matter by buying up the Heilmann wool comber for the sum of £30,000. Lister never used the rights he had bought except as a means of keeping rivals out of the field. In 1852 Messrs. Preller, Eastwood, & Gamble took out a patent for improvements wrought upon a machine invented by Mr. Preller in 1842. In several respects this machine has a resemblance to that of Lister. Accordingly the latter raised an action for infringement of patent rights and succeeded. Again, in 1854, a mechanic named Crabtree took out a patent for an improvement on Messrs. Preller, Eastwood, & Gamble's machine, and the holder of the Heilmann patents sought the right to prevent Crabtree from selling his machine on the ground that it was an infringement of patent. This also was decided in favour of Lister.

In the midst of this strife, and, happily outside of it, the combing machine continued to develop and improve. As a consequence, the number of different wool-combing machines at present in actual use is very great. We venture, therefore, only to sketch a few typical machines, at the risk of passing over the experience of thousands of textile workers.

The Lister or Nip Comb.—This is really two machines combined in one—the gill box and the comber; but there are important modifications in detail. Fed from a number of sliver cans the soft ropes of wool are carried on to the faller gills, slightly curved, the centres being lower than the ends. The fallers are closely set together, and each one has three rows of teeth. As each faller comes forward the dabbing brush, working on an eccentric cam, presses the wool down into the pins. Just at the point where the faller drops, a pair of nippers come forward and catch into the wool, holding it taut, while the faller retreats. The nippers swing back and encounter a carrier comb swaying forward in the other direction. Caught in the teeth of the comb, the wool is dragged from the nippers, which then open and swing back again to the faller gills. Continuing its course, the carrier comb comes up to the large comb circling round, and casts the wool over it. At the same moment another dabbing brush descends and thrusts the wool deeply into the teeth of the circling comb, which passes onwards, always receiving from the carrier fresh supplies of wool, so that the fibres crowd upon it to the extent of overlapping; but the drawing-off rollers are waiting ready, and they draw the fibres through the comb and send them off through the delivery channel to be formed again into a sliver for the spinning department. To guide the wool straight, and aid the drawing rollers to take hold of it, a blast of air is kept constantly going over the machine, the strength of the blast being proportioned to the length of fibre being combed. Very long lustre wools, such as Lincoln, Leicester, and mohair, are very well suited by this comber. It certainly works thoroughly, combing the wool no fewer than four times. It combs in taking the wool from the fallers; between the nippers and the carrier comb; between the carrier and circling comb; and it finally combs by the drawing-off rollers out of the circling comb.

Holden Comb.—The relation between the screw gill and the comb on the nip combing machine is quite reversed on the Holden square-motion comb. Fed from balls placed upon carrier rollers, or drawn from sliver cans, the wool is taken into the machine by two pairs of rollers with a very peculiar motion, like the to-and-fro movement of a loom slay. Bearing the thick slivers, the rollers swing almost to within touch of the comb and then recede, leaving a tuft of wool behind, combing it out as they retreat. A brush dabs down the wool on the comb, which is double, one row of pins fine and one coarse. Within the circle a presser knife supplements the efforts of the dabbing brush

to put the wool well down into the teeth of the comb. At one side of the comb a semicircular set of gill bars are constantly bobbing up at the side of the comb and rushing off in haste with as much of the wool as they can seize. A brush assists them a good deal, having a rocking motion just over the comb, and always brushing out the fibres over the points of the fallers. Drawing-off rollers and delivery apparatus complete the action of the Holden square comber.

The Eastwood Comber.—One of the handiest and least pretentious of combing machines, the Eastwood, is specially suited for dealing

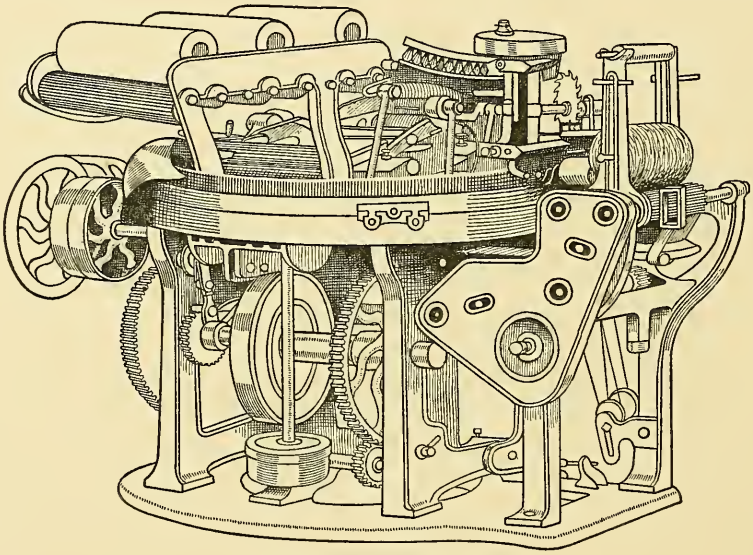


Fig. 83.—Platt & Eastwood's Comb

with short, medium, and fine wools. The principal parts of this machine are: 1, a circular comb, 3 ft. 6 in. in diameter; 2, feed board containing three laps of gilled wool; 3, feeding apparatus inside the circle of the comb, comprising eight faller gills and a cylinder with six pairs of nipper jaws; 4, drawing-off rollers outside the circle; 5, stripper knives inside the circle; 6, delivery apparatus, either for balling or coiling the sliver in a can.

Drawn from the laps, the wool is fed to the fallers by rollers having an intermittent motion, and carried rapidly by them within the nip of the jaws of the cylinder. Drawn from the fallers by the cylinder's nippers with a combing action, the tufts are thrown by the revolving cylinder over the circling comb. The rollers outside take hold of the wool and pull it through the comb. In this manner the fibre is

thoroughly combed. On some machines the resultant sliver is balled, and on others it is merely coiled into sliver cans.

Noble's Combing Machine. — Known as the circular combing machine (fig. 84), this is the highest form of comber yet invented. It is very complex; but the complications arise from the number of

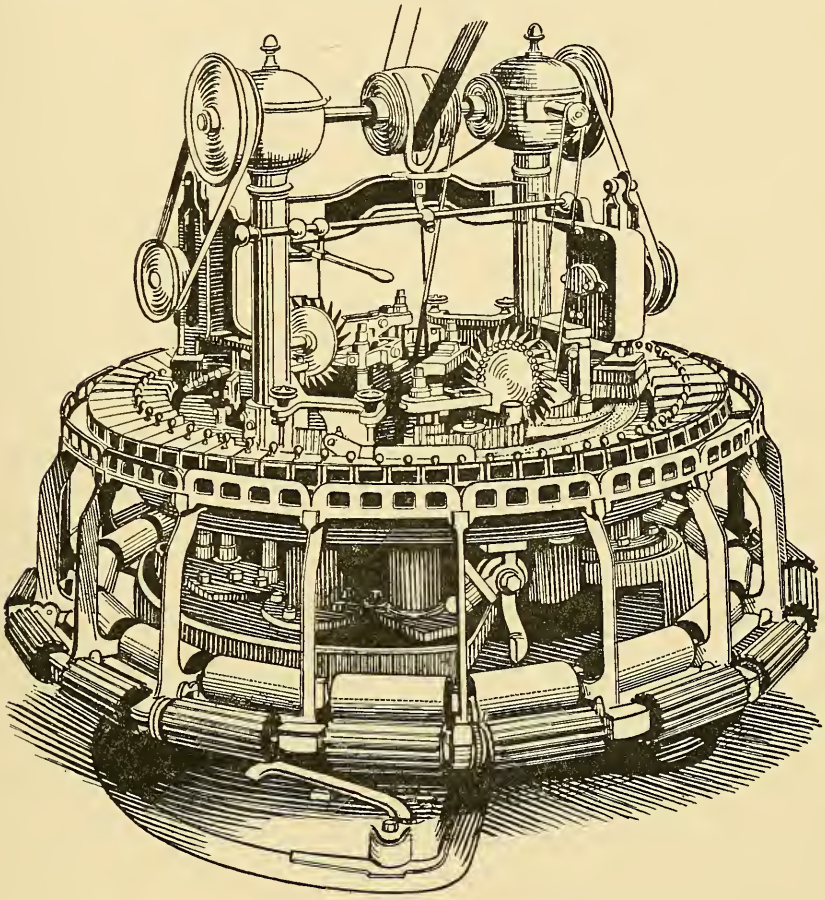


Fig. 84.—Noble's Combing Machine

ingenious contrivances which, combined with the heat of the steam chest, effectively work together to produce the best results.

Specially wound on bobbins in fours the slivers are placed all round the outside of the machine. The bobbins rest on a pair of rollers, one corrugated to give the bobbin motion. Each sliver is passed through a separate feed box, which is hinged to hold the sliver up. On each side of the machine works a dabbing brush, having an alternate motion of high speed. Another tool or pair of tools are the star-

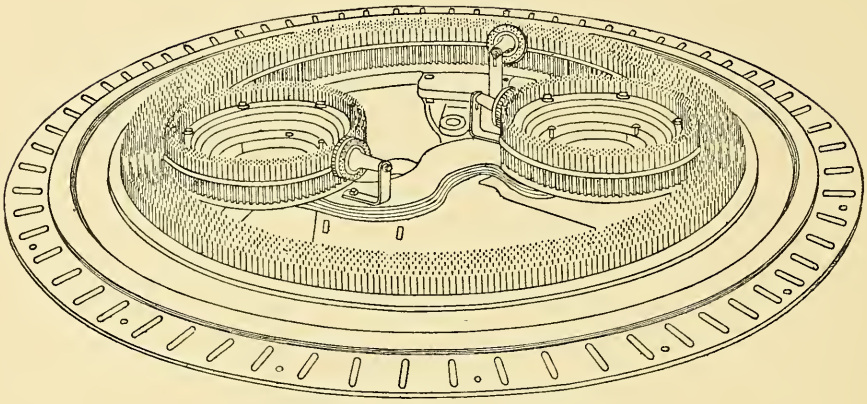


Fig. 85.—Noble's Comb: the Large and Small Circles

pointed wheels named the dividers, always visible on the top of the machine. Looking farther in we see a set of combs curiously adjusted

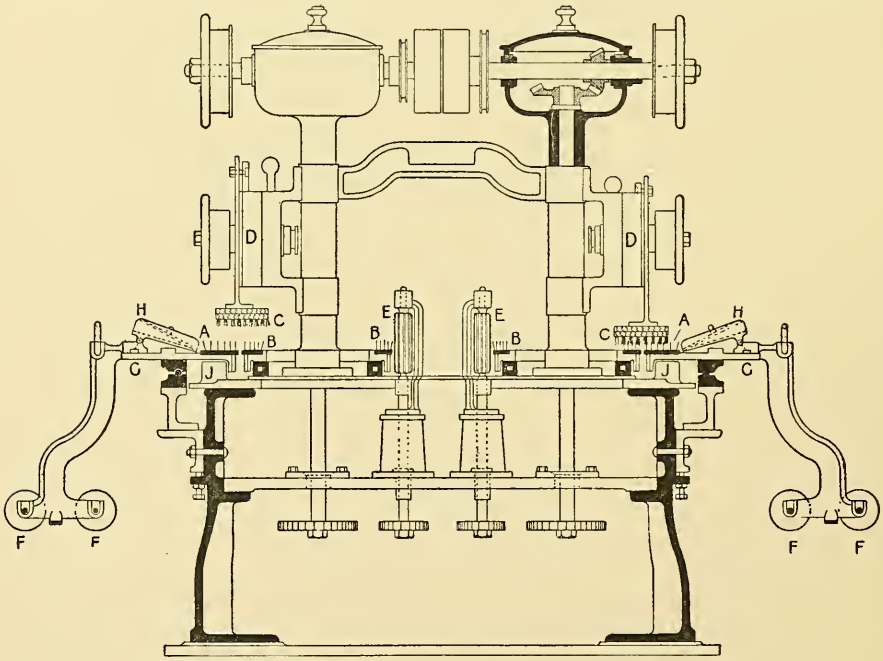


Fig. 86.—Section of Noble's Combing Machine

A, Large circles. B, Small circles. C, Dabbing brushes. D, Dabbing motion. E, Drawing-off rollers. F, Creel rollers. G, Rack plate. H, Conductors. J, Steam chests.

to each other. One large comb (fig. 85) with several sets of fine teeth encircles the whole inner circumference of the machine; the other two form small circles on each side. At both sides of the large circular

comb, in close touch with it, are two vertical drawing-off rollers, each with a guide belt; on each of the small combs two pairs of rollers revolve. On the inner side of the wide circular comb and between the rows of teeth is a clearing knife which gradually tapers to a point.

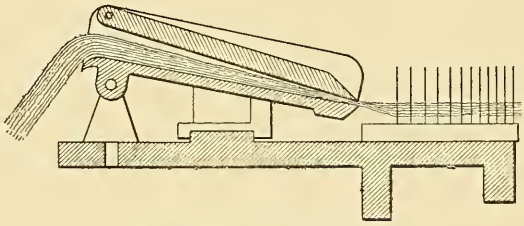


Fig. 87.—Fibres laid in Comb

Having looked at the principal parts of the machine, let us endeavour to follow out its working (fig. 86). The wool is drawn in from the feeding boxes (figs. 87, 88) at the moment the large and small combs begin to move, and is pressed down into the pins of the combs by

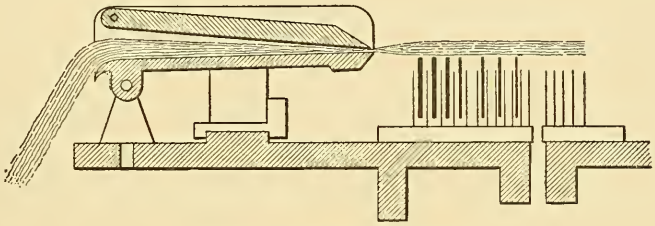


Fig. 88.—First Motion of Conductors

the dabbing brush. The wool is straightened out by being extended between the small and great circles of combs. Being so different in size, the small revolving with the large, the two sets of teeth go farther and farther apart as they recede from the point of contact, and so stretch the fibres between them.

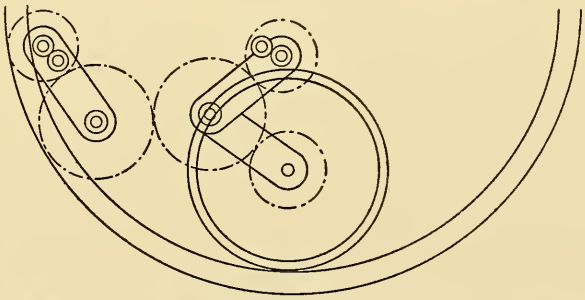


Fig. 89.—Noble Comb. Diagram showing gearing of circles to drawing-off roller shafts to allow of alterations in the relative positions of those parts

At the widest stretch the dividers come into play, stroking down and equalizing the ends. The wool hanging on the inside of the large comb, and those on the outside of the small combs, form the "top" or finished sliver; the short filaments remaining on the inner circles are noils, which are cleared away by knives. All goes on in

regular succession. The fibres have been fed into the machine, and outer and inner combs have parted the material between them. The dabbing brush drives the fibres deeply into the teeth of the combs, and as they revolve the two sets of teeth stretch them out. When stretched to the fullest point, the drawing-off rollers are at hand (fig. 89), and the guide belt sends the fibres in between them, while they pull it clear. The fibres remaining are lifted out by the knives, and let themselves be conveyed over the steel plate to the dabbing brush, which immediately feeds the wool once again to the combs.

The two combings from the large circle and the pair from the small circles are led through brass funnels on to the centre pressing rollers, where each pair is combined into one. The two ribbons thus formed are pressed into a single sliver on the smooth horizontal presser rollers, whence the sliver is delivered into the cans. The fine quality of sliver produced from the circular form of comber is a product of which any industry might well be proud. It is smooth, clean, regular, and evenly laid.

Cotton Combing.—When Heilmann brought his combing machine to this country he boldly claimed for it almost universal application to textile fibres. Cotton manufacturers, proudly conscious of possessing a series of wonderful machines, gave the comber a very cold reception; but of late years combing has become a common practice in the cotton industry for the preparation of slivers to be spun into high counts.

Nasmith Cotton Comber.—Some deficiencies were found in the Heilmann comber, and inventors set out to discover remedies. The overlap of the piecing on the Heilmann was too short; the roller gripped too far in on the tuft of fibre; and, in general, improvements were to be expected on a machine over fifty years old. It is only in small details that the new machines improved on the older one; the principle of working remains practically the same. Some makers retain the old name, but others name their machines differently. The Nasmith comber is a typical instance. Held down by the nipper, the cotton is first combed by the needles passing through. Before the needles have passed, the nipper has resumed work and is moving forward in the same direction as the cylinder, thus reducing the effective speed at which the needles are being drawn through the cotton and easing the strain on the fibre. As the last row of needles passes under the detaching rollers, the latter turn backward, and owing to the top roller leaning towards the cylinder, the end of the combed fleece thus

delivered backwards is projected into the space between the last row of needles and the plain segment whose front edge strokes the fleece against and under the bottom roller, so as to present a clean surface to the advancing nipper tuft for piecing. Meantime, the nipper having opened, the lap end rises automatically and points directly towards the nip of the rollers. It would rise higher, but is met by the falling top comb and kept in proper position. The detaching rollers now

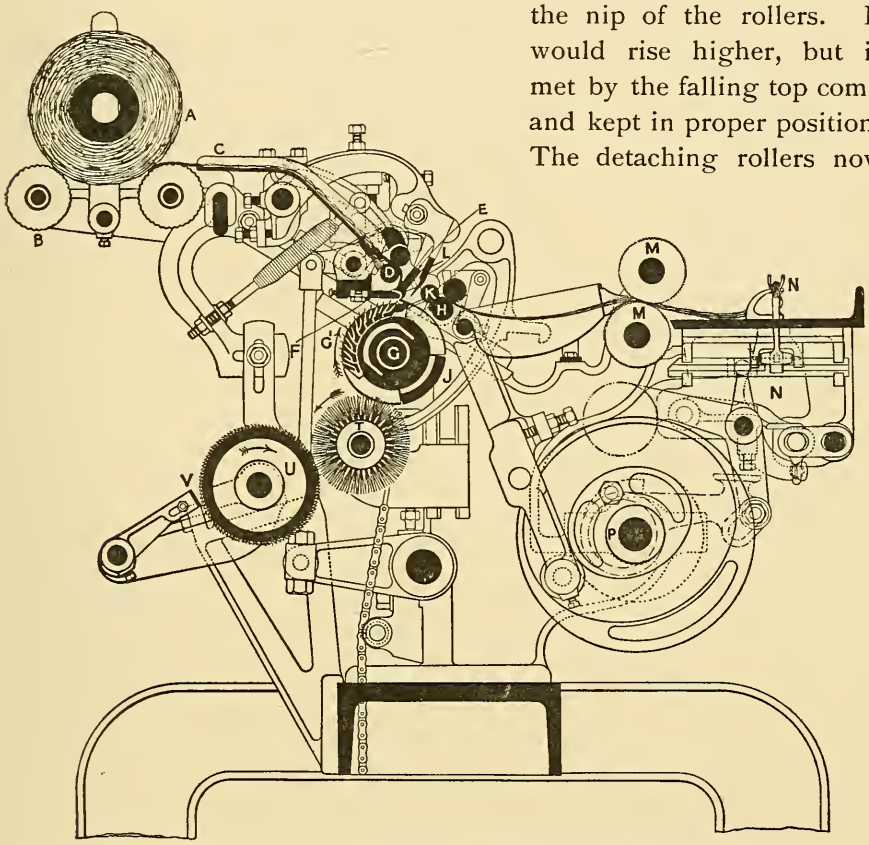


Fig. 90.—Heilmann Cotton Comber. Section showing nipper bar and cushion plate in contact; comb cylinder commencing to comb the tuft of cotton and the top comb lifted.

A, Lap, 10½ in., 11 in., or 12 in. wide. B, Wood lap rollers. C, Lap plate. D, Feed rollers. E, Nipper bars. F, Cushion plate. G, Comb cylinder shaft. G¹, Comb segment. H, Top and bottom fluted detaching rollers. J, Fluted segment. K, Detaching roller covered. L, Top comb. M M, Sliver calenders. N, Patent tumbler stop motion in sliver plate. P, Cam shaft. T, Brush. U, Doffer covered with inserted wire. V, Noil stripping comb.

begin to turn forward and seize the tips of the fibres presented by the advancing nipper and pull the lap end into the top comb. The nippers continue to advance, but with diminishing speed, approaching the dead point of the crank, thrusting the end of the lap gradually into the nip of the rollers, which successively seize fresh fibres and draw them off through the comb. The top roller moves away before

the advancing nipper and top comb, but is eventually overtaken by them as both nipper and roller arrive at the end of their respective paths. The rollers continue their rotary movement an instant longer, to commence the separation, which is completed by the withdrawal of the nipper and comb, leaving a short combed end projecting from the rollers, and the process recommences.

Platt's System of Cotton Combing.—Heilmann's patent having long expired, adaptations of the principles of his machine are numerous. Messrs. Platt Bros. have devised both a highly improved Heilmann comber and a system of cotton combing, with necessary appliances. "In order that the cotton may be in a suitable form and condition for combing, the card sliver is passed through one passage of drawing and made into a lap by the sliver lap machine. Another system is to displace the drawing frame at this stage, and insert a ribbon lap machine between the sliver lap machine and the comber. In the former system the doubling takes place in the sliver, and in the latter in the lap, both systems, however, having the definite object of obtaining a uniform lap, with the fibres of cotton in the greatest possible degree of parallelism, so as to be in the most suitable condition for combing."

The sliver lap machine, as the name implies, serves to unite and form into a narrow lap those slivers which have been previously passed through the drawing frame preparatory to combing. A form of the machine commonly employed combines 20 slivers into a lap 12 inches wide. In principle and operation, the machine is so simple as to require no description.

The Heilmann comber (fig. 90) is employed in this system and closely resembles the Nasmith comber already described. As shown in the diagram, some minor parts differ, but the actions are similar.

CHAPTER IX

Felt and Felting

Felt.—Felt is a cloth which is not woven. No thread enters into the composition of this fabric. In its simplest form felt is a layer of wool the component fibres of which have been pressed and tangled into unity. The patron saint of the felt makers is St. Clement, who, when starting on a pilgrimage, put carded wool between his feet and

the soles of his shoes or sandals, and found at his journey's end that the wool had been converted into cloth. The worthy Clement made no new discovery, for felting had been practised many centuries before his time, but the story illustrates the felting principle in a very simple and picturesque manner. The wool fibres, constantly subjected to the saintly pilgrim's feet, and moistened by his sweat, were wrought into close union and became a solid piece of felt.

Let us try to dissect a piece of felt. It does not fray out thread by thread, like woven cloth; in tearing off a fragment we produce a ragged hole, and the piece torn off is very irregular, consisting of long and short fibres pointing in every direction. The fibres are intimately intertwined, and hold together tenaciously. It is difficult to dissect a piece of well-made felt, the fabric seeming to be rather a natural unity than an artificial combination. However, by dint of patient labour we reduce the fragment of felt to its component parts, and obtain nothing more than a little heap of wool. Without the intervention of spinner or weaver this heap of fibres was made into solid cloth, smooth in texture and fine in quality. The fact is wonderful and calls for explanation.

When examining the various wools under the microscope, we saw reasons for modifying the theory of felting hitherto commonly accepted. The simple and easy explanation of felting as the gripping into each other of deeply serrated fibres, under pressure, is not in accordance with fact. On the best felting wools, the scales are not deeply serrated, while wools of little use to the felter show scales comparatively pronounced. Crimpiness, flexibility, and hygroscopic quality, combined with delicacy of fibres, are the most important factors in felting. Expanding with moisture, contracting with dryness, responsive to alterations of temperature, and tending to crimp and curl, the wool fibres, under elastic pressure, draw closer and closer into each other. Presenting a delicately uneven surface, the scales of the wools undoubtedly contribute to the felting action, and help to render the combination of the fibres permanent. The wonderful tenacity of felted fabrics, therefore, is explained by the essential nature of wool itself. This is as it should be; the finer and stronger the wool, the finer and stronger the felt.

Kinds of Felt.—No wool fabric has so wide a range both in quality and use as felt. It takes many shapes and serves numerous and widely different purposes. Two causes contribute chiefly to the variety and generality of the fabric. First, the felting process is cheap; if it is

required that a fabric be produced at the lowest possible cost, a single operation will suffice to change the washed wool fibres into a kind of felt, strong and elastic. Second, the very simplicity of the productive process lends itself to easy variation, a slight modification in procedure changing totally the character of the product. We have also the fact that where the manufacturing process counts for so little, the raw material must count for a great deal; a difference in the wool supplied to the felting machines makes a different felt. The large variety of felts are classified under four heads: 1, *hat felts*; 2, *dress felts*; 3, *industrial felts*; 4, *carpet and domestic felts*.

Hat Felts.—The most primitive form of head covering is the pad of felted wool with which the inhabitants of the tropical East protected their heads from the fierce rays of the sun. The felted pad has since been shaped into the fez of the Turk, the steeple-crowned hat of the early Puritans, the broad-brimmed and feathered headdress of the Cavaliers, the cocked hat of the eighteenth-century gallants, the shovel hat of the English episcopal clergy, the common bowler, and the large variety of slouch, sombrero, hard and soft, high and low felt hats now worn by civilized mankind all the world over. Variation in shape has also brought on change in material, the fur of the rabbit, hare, and beaver being called upon by the voice of fashion to supplement wool. The maker of hat felts is a specialist and stands outside the textile industry; or perhaps hat manufacture should be described as a highly specialized branch of the textile trade. In all hat felts there is a certain degree of stiffness, differentiating the material from ordinary felt cloth; but the nearer hat felt approximates to cloth in softness, lustre, and flexibility the better the quality.

Dress Felts.—Unlike woven cloths, felts do not command a steady sale in the dress-goods market. The fabric is never wholly absent from the shelves of the drapery warehouse, but wide fluctuations in the market exercise a depressing effect on the industry. Under normal conditions felt is constantly in demand for men's heavy overcoats, cloaks, capes, and other heavy winter wraps. Ladies require a greater range of cloths. Felt drapes well, and therefore makes a fine material for riding habits and heavy walking skirts. Fashion occasionally favours the fabric as a dress material, but the vogue seldom lasts. More constant is the trade in strong felts for jackets and winter cloaks, driving coats, and trimmed opera cloaks.

Industrial Felts.—The soft density of the felted fabric renders it very suitable for use as a pad or spring in many machines. Because

produced by pressure, felt has naturally a very smooth and solid surface; impervious to water, lasting, flexible, durable, it is the common drudge of industries of all kinds.

Plumbers find felt useful in a variety of ways. It serves as a washer for water taps, a cover for pipes, a pad for pipe bends, a rest for earthenware fittings, and many other uses. Indiarubber has displaced felt in several departments of plumber work; but rubber is a costly material, and the plumber adopts felt, as the cheaper article, wherever he can.

Another direction in which felt meets the strong competition of indiarubber is in the blanketing of printing-machine cylinders. The printer requires a smooth, hairless, elastic, yet solid covering for the printing cylinders of his machine, to interpose between the delicate surface of the type and the hard surface of the heavy pressure cylinder. Since ever the printing press was invented the felt blanket has been accepted as the most suitable medium for regulating impression; but the invention of swift rotary machines, combined, it must be said, with faulty workmanship on the part of felt manufacturers, let in the rubber and composite blankets.

Felt is universally accepted as the most suitable carrier of light and fragile materials from one process of manufacture to another. Hence it is the foundation of numerous endless-lattice feeders and carriers in a wide variety of machines, ranging from the biscuit-baking machine to the cotton opener. Paper-makers are large consumers of felt, long and broad sheets of the fabric being required on the drying cylinders, conveying the tender material round the great steam-heated rollers. Felts for this purpose must be smooth, clean, and hairless, as well as of considerable tensile strength.

Saddlers and harness makers consume large quantities of felts. The finest inside linings of saddles, collars, breechings, and knee pads are made of felt. Horse blankets, saddle cloths, and hoods are generally made of felt, though woven fabrics are sometimes preferred for the sake of economy.

Perhaps the highest and best market for the felt manufacturer is that represented by the furnishing trades. Billiard-table makers, upholsterers, and cabinetmakers are good customers of the felt industry. The soft, smooth, elastic surface demanded by the billiard player is provided by felt well made and firmly calendered. If of good quality, felt remains unchanged under variations of temperature, and this is an indispensable requisite of billiard-table covers. Made

specially, those felts are dearer to buy than the rival baizes which are woven for the purpose, but they last very much longer.

The cabinetmaker takes a considerable quantity of smooth felt for linings and paddings; but it is in the upholstery department that the greatest quantities and most numerous varieties of felts are consumed. Coverings, paddings, hangings, draperies of all kinds are made of felt. The fabric is the most pliant of materials; it takes on and retains colours, and imparts to the dyes a soft rich lustre grateful to the eye. Decorative felts are manufactured in large quantities, ranging in quality from the light hangings of the gala day to the costly and highly embroidered draperies of the palaces of the great.

Felt is largely used for covering buffing wheels in various industries. Glass-makers require heavy buffing pads made of felt 2 in. thick, and the fabric serves as a basis for the polishing emery of wood and metal finishers.

To the musical-instrument makers felt is an indispensable material; it forms the pad for keys and stops in all kinds of musical instruments. The very finest class of felt covers the hammers of piano keys. To the makers of the last-named instrument the quality of the felt supplied them is a most important matter.

Builders' felts are a class by themselves. For the damp courses above the foundations of walls, and for the linings of roofs, felts of a coarse but genuine quality are demanded. Mixed with asbestos, felt makes an excellent fire-proofing material.

In minor degrees felt enters into many other industries; it is a substitute for leather, rubber, and other costly materials. We are of opinion that the industrial field has not been fully exploited by felt manufacturers; we also know that some portions of the trade have been lost through indifference to quality. This specially applies to the coarser grades of felts, some manufacturers apparently being under the delusion that coarseness also implies impurity and careless workmanship. In the manufacture of building felts and brattice cloths for mines adulterations with jute became so common at one time that substitutes for felt were sought and found. In this, as in most industries, the avenues to fortune are yet open to honest energy and enterprise.

Domestic Felts.—Capable of receiving a smooth and lustrous finish, felt is much favoured as a material for table covers, sideboard covers, shelf and cupboard draperies, and various hangings. The soft nature of the fabric lends itself to those flowering ornaments dear to the

feminine soul. A large trade is done in felts stamped with patterns for home manufacture and decoration. Heavier felts make good sofa blankets, bed mats, and rugs. The linings of skin rugs are almost invariably of felt. The largest branch of the felt industry, however, is that employed in the manufacture of felt carpets and carpet felts. Though the names of those two fabrics are composed of the same words reversed, they are totally different classes of material. Felt carpets are dyed or patterned floor coverings; carpet felts are commonly coarse felts, in the natural colour of the wool, designed to lie under the costly carpets and save them from the wearing contact of the floors. Owing to the competition of the low-priced tapestry carpets on the one hand, and the linoleums and oilcloths on the other, the carpet trade has not grown much during recent years. Yet the felt carpet has many recommendations; it is comparatively cheap, pleasant to the foot, lasting, and may be made harmonious in colour and artistic in design.

The British Felt Industry.—Felt manufacture is a closely localized industry; outside the Rossendale district of Lancashire there are very few factories of importance. Having in mind the shortness and simplicity of the manufacturing process, we require some explanation of this fact. At first sight it would seem possible to manufacture felts successfully in any wool-producing district, but when we know all the factors in the case the present state of matters seems inevitable and just.

Before the coming of the machine factory, felt-making was a handicraft cottage industry. Felting was, in fact, a method of using up the waste wool left from the carding or combing. But when the spinners and weavers were drawn into the woollen and worsted factories and the raw materials of felt-making accumulated, it was inevitable that the felt factory should also arise. With so much cheap raw material at hand, felting factories naturally became established in many of the centres of wool manufacture. Economic forces, however, gradually concentrated the industry round Leeds. Being the seat of a great wool market, in the heart of the wool-manufacturing district of Yorkshire, Leeds seemed to be ideally situated for carrying on the felting industry successfully under factory conditions. For a period the great Yorkshire town held the bulk of the felting trade. The manufacturers made the felts and sent them over the hills into the valleys of Rossendale to be dyed and printed, taking the goods back to be finished and packed. This system worked well till the

railways made roads across from Lancashire and the coast to Yorkshire, incidentally providing the valleys between the two counties with outlets to the coast. The reason why Leeds manufacturers sent their goods to be dyed and printed in those lonely vales was that there copious and pure supplies of water are readily obtained. But felting also demands large supplies of water. With the way opened up for the transmission of raw materials and finished goods by the railroads, the transfer of the whole industry from the Yorkshire town to the Lancashire valleys was rendered feasible and almost inevitable. In a large centre of population water is a costly material, and labour must be paid at such rates as enable the workers to live in a community where the rents and other indispensable charges on living are comparatively high. Special industrial efficiency is developed in the towns, and this factor alone has enabled Leeds to retain a considerable portion of the felt trade; but the great bulk of the industry has been carried over into the Rossendale district. From Rawtenstall up to Waterfoot and beyond it, the Whitewell Vale and neighbouring valleys are dotted with felting factories, employing thousands of operatives. The industry is unified; felting, dyeing, printing, and finishing are all carried through in connected establishments. At Lancaster, Leeds, and a few other towns various felts are made, but the bulk of the industry is carried on in Whitewell Vale.

Raw Materials.—Alone among wool workers, the felt manufacturer can take a whole fleece from the sheep's back and bring it out in the form of cloth. We do not recommend the practice, but make the statement because an important fact is implied in it. While every other branch of the wool industry rejects some portion of the fleece as unworkable, the felt factory recognizes no waste. Length of staple, so important in the worsted factory, is a second-rate quality in felt making. Very short wools make good felt. East India wools, deemed too short and harsh by the fine-cloth makers, and the portions of the fleece too short and rough for spinning into yarns, can be utilized in the felting factory. Skirtings, carding waste, and noils find ready purchasers in the felt manufacturers. Here we come upon one of those cross currents in the progress of industry which baffle the outside observer. Improvements in machinery and the enlarged demand for low-class cloths have enabled both woollen and worsted manufacturers to use up more and more of the whole fleece. Whereas in the middle of the nineteenth century liberal skirtings and all the sort-

ing numbers above ten, with carding waste and noils, were bagged for the felt maker, at the present day the skirtings are very thin and the wastes from carder and comber are greatly reduced and very often kept for use in the factory. The felt manufacturer thus finds his supply of raw material seriously shortened. But that is not all; the short, harsh wools of the Tropics, once regarded as the sole property of the felt maker and carpet manufacturer, have been found serviceable in the manufacture of imitation Harris tweeds and other hand-woven cloths. From friendly customers for materials otherwise valueless to the cloth manufacturers the felt makers have been forced to become competitors in the wool markets. A double effect has proceeded from this cause. So long as they had a cheap raw material for the lower grades of goods and a comparatively cheap material in noils to mix with the fresh wools for the highest classes of goods, felt manufacturers were enabled to put cloths on the market at prices little above the average prices of raw wools; now they must compete keenly for the limited amount of waste available and go into the open markets to buy most of their wools.

These facts explain the comparative dearness of genuine felts. Another and more grievous fact here comes into view. Cheap felts are sold every day, and the question is asked: Where do these come from? We regretfully admit that there are dress felts sold which are composed of shoddy, loom dust, and vegetable fibres held together with size, a little wool being added to give the fabric an appearance. Some builders' and industrial felts, of coarse grain, are adulterated with jute. It is not always easy to detect those sophisticated fabrics. The simple test of applying flame to felts suspected of containing vegetable matters has been quite discounted by the manufacturers. A touch of sulphuric acid, however, is nearly always sure.

As may be inferred, the raw material of the felt maker is wool, every kind and class of wool. From any clothing wool we can produce a corresponding felt. No fabric shows so clearly the material of which it is made; a fine wool gives a fine felt, and a coarse wool a coarse felt. By judicious blending we are able to produce cloths which seem to contradict the rule; but it only means that the blend is more suitable for producing a given quality of felt than any single kind of wool.

For felt carpets, East India and the coarser home wools make excellent raw material. Blackface and cross-bred wools may be freely

taken for carpets, because they are generally dyed and printed, and all those wools are noted for dyeing quality.

Preparation.—In the felt factory the wool is taken through the ordinary operations of preparing up to the carder. Here some variations are observed. The felting process requires that the wool should be absolutely free from oil and grease. Oiling is therefore omitted and the wool kept partially damp. Other variations are practised at the carders. Some manufacturers take the wool through the first and second carding engines, forming a sliver at the end of the latter which is fed on to special batt frames; others doff the wool in the shape of a sheet and send it through the scutcher and lap-forming machine. Both processes have points of merit, and they are practised in factories of equal standing.

Scutching and Lap Forming.—We take the older and more common process first. The wool scutcher differs very little from the cotton machine of the same name. In this case the machine is called upon to serve three purposes, viz. mixing, cleaning, and lap forming. The wool is doffed from the second carder in the shape of rolled sheets. To obtain a mixture, three or four carded sheet rolls are hung in front of the feed sheet of the scutcher, and the sheets are led in one thick mass to the feed rollers, of which there are two pairs. Deeply fluted, the first pair of rollers draw in the combined sheets and send them on to the second pair of rollers, which, revolving at higher speed, pull the sheets to pieces and feed the material to the beaters. Under three beaters the wool is further broken up and mixed, and in that condition driven along a curved grid, slanting down towards a moving lattice which carries the fibres forward to the lapping rollers. Blown upon by the exhaust fans working underneath, the wool is flattened down on the lattice, and goes smoothly under the pressure of the rollers. These rollers press the wool into a smooth and continuous sheet; but they also have the function of regulating the thickness of the sheets. As a rule, the maker of fine felts wants a lap sheet containing the same amount of wool as one of the four carding-machine sheets, only more firmly compressed. Such being our aim, we put a strong pressure on the rollers and send them round at four times the surface speed of the feed rollers, if four sheets have been fed, and three times if three sheets. The lap comes out on to the lap rollers in the shape of a fine thin sheet. If a sheet twice the thickness is desired, the draft between the lap-forming and feed rollers is lessened proportionately. For certain kinds of thick felts a lap 2 or 3 in. thick

is desired; in that case the lap rollers do not drag, but hold back, revolving at slower speed than the feed rollers, thickening and pressing the lap accordingly.

The Batt Frame.—Instead of doffing the wool from the carder in a sheet, we sometimes draw it off in the shape of a sliver. It would be possible to feed the sliver on to the scutcher by means of the Scotch feed, but the batt frame obviates the need for the scutcher and sends the wool directly on to the felting machines, if necessary. Placed behind the second carder, the batt frame (fig. 91) consists of an endless web of canvas stretched between rollers. At the front the carrying canvas is extended between a roller at the bottom and a roller at the head, with two pairs of rollers in the middle to convey the sliver and stretch the canvas; at the back six rollers, one above the other, act as the necessary complements. When the sliver comes out from the carder, it is carried up on the canvas and round through the frame, each line of sliver being added to the other so as to form a thick lap, which is doffed at the bottom of the machine and wound on the lap roller.

At one time the general opinion of the felt-making trade was decidedly against making the wool into the form of a sliver. Besides being regarded as needless trouble, it was feared that the sliver would show lines and streaks on the cloth. Neither objection has been upheld by experience. Being drawn out to their full length in the sliver, the fibres can be combined to the greatest advantage; united in a sheet on the batt frame, the lines of the sliver are completely obliterated. While repelling the main objections to the newer method, we by no means suggest that the scutcher should be altogether discarded. The whole question may be determined with the decision that both are equally good, but for different classes of work. In the felt-carpet factory the common procedure is to put the wool through the scribbler only, and then through the scutcher and lap-forming machine. If the single carding is not sufficient to mix the fibres, then the scutcher comes in as a suitable supplement. Sometimes the laps are put through the scutcher again, when the blend of wool has been composed of wools differing widely in character. Admittedly the beaters tumble the fibres about a good deal, and some may double and twist in ways not intended; but this may be an advantage in a thick fabric, and the draft of the lap-forming rollers tends to spread the fibres to their full length.

On the other hand, dress felts are very thin and the fibres must be

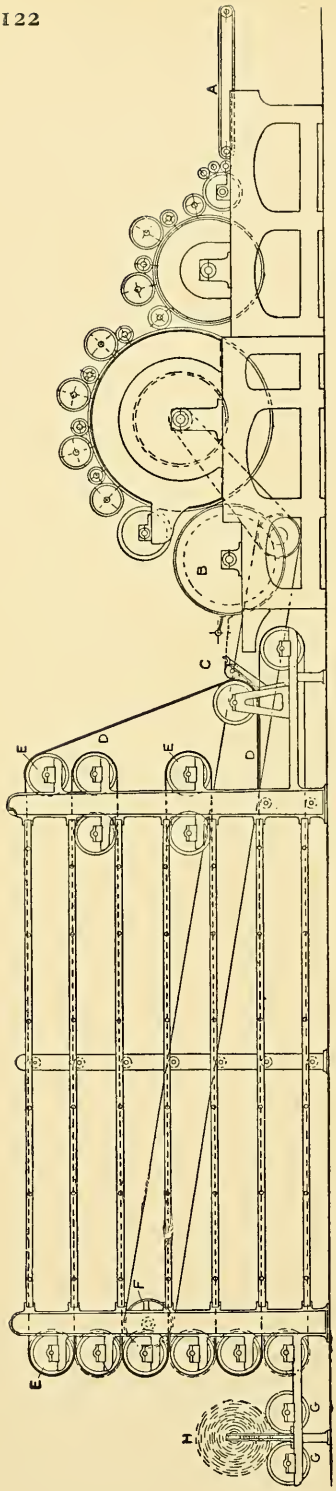


Fig. 91.—Batt Frame

A, Lap passing into the carder. B, Doffing cylinder. C, Feed sheet of Batt frame. D, Canvas carrying the sliver. E E E, Working cylinders. F, Drive. G G, Receiving rollers. H, The complete lap of wool.

very carefully laid. To obviate the risk of doubling or folding, and to spread out the wool to the utmost, the second carder is employed and the sliver is formed. A very small knot is a weakness in a fine felt. The draft of the sliver-forming apparatus gives just the necessary security for preserving the straightness of the fibres effected on the carder. Of course there remains one very clear objection to the employment of the second carder. Carding acts destructively on the valued scales of the wool fibres; the second carder, being finer, combs with more severity on the fibres, wastefully breaking the scales. By careful card-setting, however, it is possible to avoid harmful injury to the scales on the wool. Otherwise the laps made on the batt frame, after the second carder, are very regular and felt well.

Primitive Felting.—Anyone can make a rough piece of felt by spreading a thin layer of damp wool on a flat surface and kneading it all over with the knuckles of the one hand and the fingers of the other. If the felting has been done thoroughly, the fabric will hold together, a rough and unshapely but veritable piece of cloth. The hand method, however, has not been industrial within historic times. The most primitive process of which we have actual knowledge is that still practised by the native

felt makers of semi-civilized communities in the East. Spreading a layer of damp wool on a flat stone, the felt maker lays over it a goat skin or softened bullock hide. In his right hand he takes a heavy mallet and strikes on the wool through the hide, to which he gives a rolling motion with every stroke. The hide keeps the wool flat and imparts obliquity to the strokes of the mallet. By the combined action of the rolling hide and striking mallet the fibres are wrought into each other, crossing and combining closely. Felts of great strength and smooth in texture are made with the hide and mallet.

Another primitive method was practised up till about the middle of the nineteenth century by the hat manufacturers (fig. 92). Laying down on the bench a quantity of wool, the hat felter twanged a bow-string over it, levelling and drawing the fibres together. Then with fingers and knuckles he kneaded and confirmed the felt into a consistent fabric.

Fig. 92.—Bowing Felt

Mechanical appliances have altogether superseded those hand processes, but the principle is not altered. In both we see that the wool is allowed a certain amount of free play while being wrought into close unity. By elastic pressure the fibres are wooed into union. Force alone will not produce felt.

Carpet Felting.—The carpet-felting machine is the simplest and most easily understood of modern appliances. Over a large tank kept constantly supplied with hot water a flat iron table or bed is fixed. Across it a set of heavy iron rollers depend on bearings in the sides of the frame. The rollers are geared with a revolving and oscillating motion. At the fore end of the machine the lap of wool is hung, and the feed apparatus draws forward as much of the sheet as covers the felting table. When the feed has performed this operation it automatically sets the felting machinery going. Upon the wool on the steaming bed of the machine the heavy rollers work, revolving and

oscillating from side to side, pressing, drawing, rolling the fibres closer and closer, till what was but a soft fluffy sheet of wool only a few seconds before has become a solid piece of hard felt.

It will be observed that only a small portion can be felted at a time. One of the problems the inventor of this machine had to solve was to make every part uniform with every other. After the part has been sufficiently felted it passes on and leaves the bed vacant for the succeeding length. But it might happen, unless some provision were made to guard against it, that one portion would get more working than another, or that the division between the felted portions would be marked, in the one case by a hollow from over-working, or in the other by a ridge from the line between the two being missed altogether. The first of these difficulties is met by a gauge which measures the number of revolutions taken by the felting rollers, and attached is a stop motion throwing the rollers out of gear as soon as the number of revolutions has been registered. Further, the action which throws the rollers out of gear calls the feeding apparatus into play. This also moves up to the set limit, and as it falls out of gear brings the felting rollers into action. The automatic arrangements save labour and lessen the dependence of a purely mechanical operation upon the uncertainties of human agency. They also provide the felt manufacturer with a very effective instrument for giving the felt exactly that texture he has designed. There are soft felts and hard felts, medium felts, thin and thick felts, the various qualities being mostly determined by the rate of feed and the amount of working put upon the wool by the rollers. With the power of adjusting both factors, the felt maker is able to produce what form of fabric he pleases.

Another method of adding to the quality of the felt, and at the same time of obliterating any marks which may appear between the successive areas felted, is to pass the fabric through the machine twice, leaving the half of the first piece first felted as a selvedge and making the edges of the divisions the centre of each part in the second felting.

Roller Felting Machine.—One of the earliest machines to be invented for fine dress-felt manufacture was the roller machine. Though improved models have been produced, this appliance is still used in many factories. Like the carpet felter above described, the roller machine has a large shallow trough of water, steam-heated by steam coils in the bottom; but there is no plate or bed for the web of wool to rest on. Instead a double series of rollers form a continuous bridge over the water trough. The under set of rollers are hollow copper

cylinders, steam-heated internally, and revolve almost submerged in the water. Resting between each pair of cylinders, and pressing against the sides of both, are a series of heavy wooden rollers, geared on an eccentric shaft which imparts to them an oscillating as well as a revolving motion. Through the entire length of the machine, and running between the wooden rollers and the copper cylinders, runs an endless canvas sheet. At the one end of the machine the lap rollers are slung on brackets, and at the other end a pair of squeezing rollers and a cloth beam are ready to receive the felted material.

The action of this machine is continuous. Led on to the endless canvas, the web of wool passes in between the wooden rollers and the copper cylinders. Against the sides of the cylinders the heavy wooden rollers work upon the wool, pressing and rubbing the fibres and drawing them together. By the time it has reached the squeezing rollers the web of wool has been well felted and made into a close and strong fabric.

Simple as the machine appears, it demands careful study and some practical experience to work it properly. The web naturally thins towards the end of the machine, and the setting of the rollers must be regulated according to the degree of attenuation which is taking place. Associated with that problem are those of the relative speeds of the rollers and the amount of felting to be given. These are practical questions and can only be answered correctly in actual working. For every different kind of fabric the machine requires to be set, the class of wool, thickness of the web, weight of the felt to be made, hardness or softness, and other particulars, all entering into the calculations.

Improved Roller Felting Machine. — Felting machinery is being constantly improved. The manufacturers discovered that the long water trough was a hindrance rather than a help in many respects, and therefore substituted for it a small trough in which to wet the endless blanket or canvas carrying the web of wool through the machine. Another discovery was that the steam-heated cylinders, working alone, besides being expensive, did not produce the desired effect. Accordingly we find in the newest dress-felt-making machines (fig. 93) a small trough of water in the fore part of the machine, through which the endless carrying canvas is run. The squeezing rollers at the end are thus rendered unnecessary, and the felt emerges almost dry from the last rollers. Similarly the steam-heated cylinders are alternated with solid iron rollers, the felting wooden rollers working between a cylinder and a roller. The alternations of temperature produced add

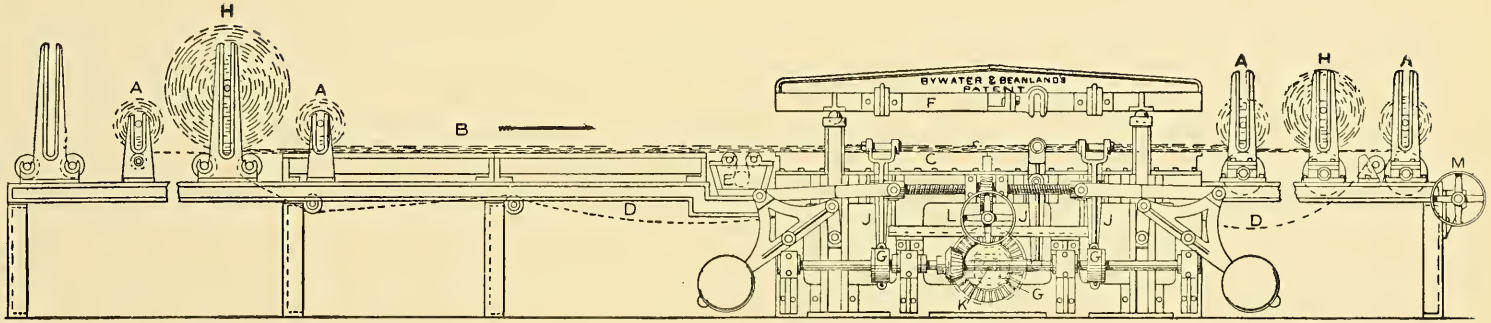
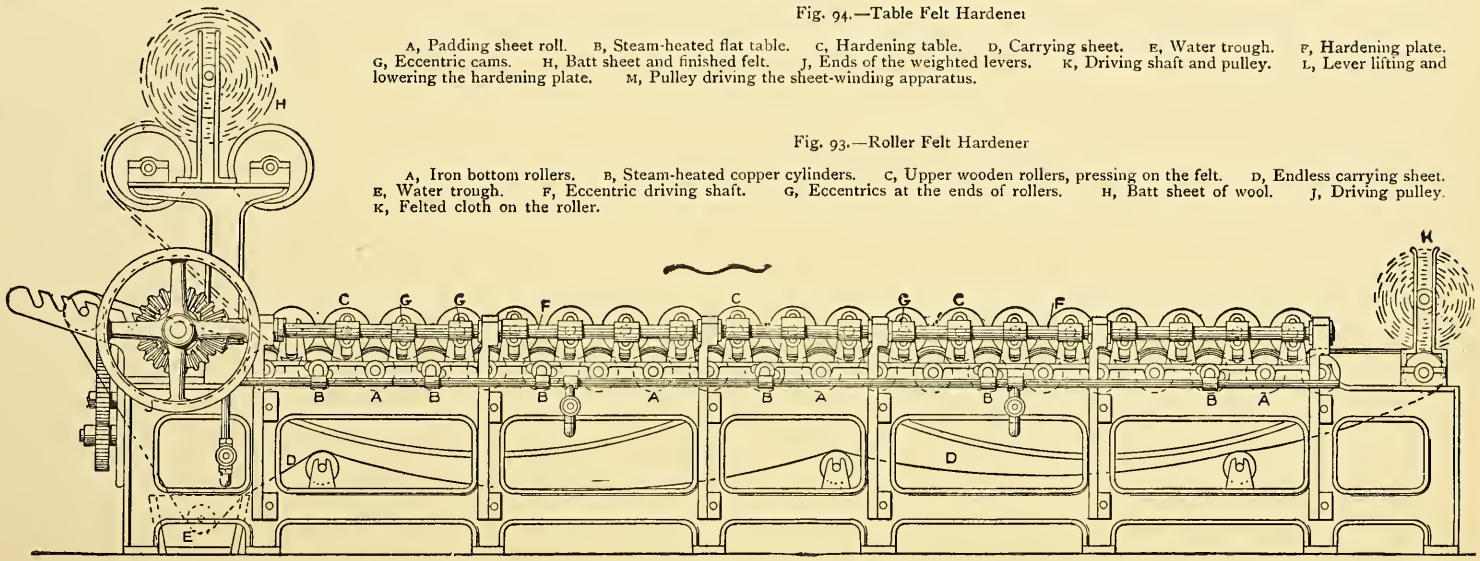


Fig. 94.—Table Felt Hardener

A, Padding sheet roll. B, Steam-heated flat table. C, Hardening table. D, Carrying sheet. E, Water trough. F, Hardening plate. G, Eccentric cams. H, Batt sheet and finished felt. J, Ends of the weighted levers. K, Driving shaft and pulley. L, Lever lifting and lowering the hardening plate. M, Pulley driving the sheet-winding apparatus.

Fig. 93.—Roller Felt Hardener

A, Iron bottom rollers. B, Steam-heated copper cylinders. C, Upper wooden rollers, pressing on the felt. D, Endless carrying sheet. E, Water trough. F, Eccentric driving shaft. G, Eccentrics at the ends of rollers. H, Batt sheet of wool. J, Driving pulley. K, Felted cloth on the roller.



greatly to the felting capacity of the machine, the wool contracting and expanding in the process. Subjected to constant change from heat to cold under continuous and rubbing pressure, the crinkling fibres are knit more and more firmly into unity.

Some of the new felting machines are very large, having as many as eighteen or twenty sets of rollers. The new machines differ little from the old water-felter in principle, and operators who have been taught to work the latter have no difficulty in learning the former.

Table Felt Machines. — Even the most perfect cylinder felting machines leave something to be desired. Felting is essentially a flattening operation, and the cylindrical motion tends to induce a curving form in the fibres which gives to the fabric a blistery look when very pronounced. The tendency is corrected in the milling and subsequent operations, but it is better that the defect should not occur. As we have seen, the felt-carpet manufacturers give the felt one flat surface upon which to form. The success of the idea has induced further experiment in the same direction.

One of the most important of the table felting machines (fig. 94) is the "Bywater & Beanlands Patent", specially notable as the embodiment of the whole history of felting. Whether or not the inventors have undertaken too much we can scarcely judge. Apart from speculative claims, however, the machine is interesting, and does good work. Beginning examination of the table felter at the feed end, we find holders for as many as six batt rollers and apparatus for a similar number of dividing canvas sheets. Here comes into view the first important feature of the machine. The primitive felt maker interposed a skin between the wool and the blows of his mallet; the same principle is embodied in the canvas sheets which hold the wool between them. At the same time the carrier canvas sheet is brought into use. Sheets of wool, dividing sheets, and carrying canvas are borne forward to the table. Just in front of the latter the carrying canvas dips down into a small warm-water trough. The table is a smooth plate of steel, strongly supported in the frame, and is in two sections, the function of the first section being to heat and smooth the felt. Steam-heated from below, the first part of the table gradually brings the sheets of wool into condition, and they pass along to the next division, which is called the hardening table. Above the hardening table is the hardening plate. It is upon the latter that the greatest ingenuity has been displayed. The object of the inventors has been to make that heavy plate of metal vibrate transversely while

pressing down upon the felt. Strong layers, with eccentric driving gear, act upon the pillars of the plate, imparting to them a to-and-fro motion as they are being drawn down on to the top of the table, while counterbalancing weights confirm the pressure. The lowering and elevation of the hardening plate are effected by one pulley, while an independent pulley drives the eccentrics imparting the felting motion. It is evident that no device has been omitted which might be imagined to contribute to the effectiveness of the machine. Delicate adjustment might hardly be expected from so heavy a machine, but by simple means the degree of pressure and the amount of felting to be given can be regulated to a very nice exactness.

Felting Agents.—From the machines and methods examined we are able to gather what are the agents employed in the act of felting. Moisture and heat are employed to soften, contract, and expand the fibres. By elastic pressure, applied in contrary directions, the fibres are brought into close contact, causing them to clasp into each other. Lying at all angles, the fibres are intricately combined, the joinings being at all points and forming a solid, firm cloth.

Purifying the Felt.—If the wools have been thoroughly purified at the beginning of the preparatory stage the duty of the felt purifier is light. But it is imperative that the higher kinds of dress cloths and most of the finer industrial felts should be absolutely free from all vegetable mixture. Therefore every felt factory has a well-equipped sulphurizing plant for destroying what traces there may be in the felts of vegetable matter. If Whiteley's carbonizing system has been employed on the raw wool the felt cloths need very little treatment, being merely put through a bath of dilute sulphuric acid and washed and dried; but if no system of destroying vegetable fibres in the wool has been practised, the felt must be subjected to very thorough sulphurizing. After being passed through a bath of fairly strong acid the cloth is partially dried and then hung up in heated chambers to make the acid act effectively. Another method is the sulphurizing process. Hung in a chamber or stove, the felts are subjected to the fumes of burning sulphur. The latter operation, however, is only effective on coarse felts or those with small traces of vegetable matter. Freed thus from vegetable matter the felt is thoroughly washed and dried.

Sometimes buyers are astonished and indignant when they find that the felt cloth supplied to them goes wrong, appears burnt up, or breaks away readily. They blame the manufacturer, and perhaps think of charging something like fraud upon him. The purifying process

is one of those operations which bring about destructive effects almost certain to escape the notice of the most careful manufacturer. It may occasionally happen that the operative has detected the error and concealed it for his own sake, but in most cases he too may be held blameless. Sulphuric acid, combined with heat, acts as a solvent on wool, if given time, or if the temperature is high. A slight mistake in the sulphurizing or purifying may have very serious effects. The cloth may give no sign of having been over-treated. It may seem quite sound and of good colour all the time it is in the factory, but the heart may have been burnt out of it all the same, and the effect is revealed in the warehouse months after. It seems a little hard that the manufacturer, at the very moment he has been endeavouring to secure purity of goods for his customers, should be unlucky enough to incur their anger and suspicion through a slight slip in the course of the process. As a rule, however, the solutions supplied to the trade, and long practice, render those mistakes very rare.

When the felt comes from the purifying room it is ready for the other department, which corresponds in a large degree with the finishing rooms of the cloth factory. Fulling, milling, bleaching, dyeing, printing, steaming, calendering, and pressing are operations common to all kinds and classes of textile goods. As we devote a special section to the finishing of fabrics it is needless to follow felt through those operations at present. It is now a cloth, though rough and unshapely. Felt depends more upon the finishing operations for quality and special character than woven cloths, but the processes are identical, the difference being in the greater mobility of the felt.

Part III.—Spinning

Part III.—Spinning

CHAPTER I

Introductory

The Art of Spinning.—The basis of the art of spinning is simple. Up till near the close of the nineteenth century examples of primitive spinning might have been seen in this country, often within sight of mills containing highly developed spinning machinery. On the fields of the small farmer the men and women made straw bands with which to bind the ricks of corn reaped by the harvesters. This straw-band making is spinning in its most original and primary form.

Among the very first tools of man the line, cord, or rope has a place. Most likely the stem of a tough creeper was twisted out of its natural position to make the nightly roost of the family more secure. To disconnect the long stem and apply it in other ways was a simple expedient. From the single strand to the doubled and twined length was another step which was doubtless accomplished without the consciousness of achievement on the part of the man, or tribe of men, that took it. Monkeys and beavers have been taught by necessity to do more wonderful feats. The doubled twigs, or withes, or reeds, gave a stronger rope; but to lengthen it was difficult. When a man thought of combining three stems, he found that he had at once secured a stronger rope, a much more flexible and rounder instrument, and a means of lengthening his line. When one strand became short he could insert the end of a new strand and make it firm by binding the other two over it. The consequences of those successive and inevitable steps towards the formation of a continuous cord out of short lengths of twig or grass have been tremendous; but in themselves they are little more than the natural

workings of animal intelligence. In the darkest realms of savagedom the primary spinning operations can be seen nakedly, the consequences not yet visible there.

We return for a moment to the old-time crofter making straw bands within sight of the spinning mill. He has a bundle of straw round his waist from which he draws as many stalks as the thickness of the rope demands. Doubling the straws over a stick, the farmer gives it to his assistant, usually a boy, who holds it by both ends while the rope maker twines more straws in by the ends. The lad twists the stick in the direction opposite to the twining of the rope spinner, who adds on length after length of straw, retreating step by step as the rope lengthens out. Thus twining, drawing, feeding, and spinning, the farmer makes a long and strong rope.

There is no essential difference between rope spinning on English fields and the same operation in the valleys of the Oxus; but we obtain a nearer view of the former. Analysis of rope making brings out the several features common to all spinning. The composing fibres are combined to the number required for the thickness of the rope; they are drawn out to full length, fed in endwise, and locked together by the twist. To sustain the twist an opposing force is applied at the end farther from the spinner. Till the twist has been confirmed, the rope is held taut to give the greatest length possible and preserve it from kinking and curling, as it would naturally do.

Thus we have the three acts of spinning—*drawing*, *doubling*, and *twisting*. The finest machinery is required to do no more.

Since ever man was able to make things, he has gone on trying to improve and alter both the making process and the thing made, seeking the highest possible return for his labour. From the dim evidence available it would appear that the twining or spinning idea was early utilized for producing breadths as well as lengths of combined stems. At the beginning both methods are equally possible. Instead of crossing the stems lengthwise and twining them round, it was open to the maker to twist the one over the breadth of the other, and add on more stems to form the length. The product is an extended flat instead of a round cord. This plaiting has developed into knitting and weaving. As we now see, the root idea of yarn spinning and cloth weaving is one.

When the idea of twisting fibres together to make cords and sheets was evolved, a wonder-working power had come into being, and the sphere of its activity was slowly opened up during the many ages

LADY HAMILTON AS SPINSTRESS

(From the painting by George Romney)

succeeding. Men and women had to acquire the need for clothing, for housing, for art and ornament, before the spinning idea could find its proper function and sphere of activity. Slow and unresting, the process of textile development went on. The reeds by the river and on the margin of the lake were called up to make shelters for the living and covering for the dead; then the fibres hidden in the reeds. When the art spirit entered the mind of the spinner and weaver he searched for fine materials in which to embody his visions of flowing robes and aerial draperies. He drew the wool from the sheep and goat, and plucked the gossamer down from the seed pods of the ripened cotton, with which to spin and weave his ideals.

When the spinner began to use a small and slender fibre instead of the long withe of grass or reed, he had to change his method of working. We ought rather to use the feminine pronoun, for it seems almost certain that the finer developments of spinning arose in the woman's domain. Her finer fingers and more delicate fancy wrought finer tissues from tenderer elements. We have seen that the long stems of the straw allow free play to two pairs of hands and a thick stick; but only one pair of very fine hands can have room to work on a hair of wool, and the fine fibre of the cotton admits only of handling even more delicate. To draw out and spin the fibres as they are given out from the fingers of the spinner, some means must be devised. How many experiments were tried we have no facilities for knowing. In the end it seems to have occurred to some genius that the stick held horizontally by the assistant of the spinner of ropes and the larger fibres could be weighted and given a rotary motion within the spinner's own control. When the idea was realized in practice, the spindle came into a world in which it has played a wonderful part.

The origin of the spindle stands just beyond the first streaks of historical dawn. Who invented it is unknown. Whether it was devised by various nations independently, or was invented by some great genius of the Aryan race or a race still older, before a prehistoric dispersion, cannot be ascertained. In the oldest legends of Egypt, the oldest in the world, we find Isis teaching the maidens how to spin the flaxen fibres of the Nile with the spindle. Here also we have an advance in the preparation of the raw fibres of which there is no historical record. The flax is ready for making into yarn, and how much that implies the reader already knows. We inherit the labours of uncounted generations of men and women.

Distaff and Spindle.—At the time when men began to write down their thoughts about the world and themselves, and gave definite form to the oral traditions of their predecessors, spinning was an integral part of the social economy. Fibres of flax, hemp, wool, and cotton were regularly prepared and hung on a stick, the lower end of which could be held under the spinner's arm, while the prepared fibres depended within easy reach of her hand. In our own language distaff means literally *bunch-stick*, and this seems to have been the kind of name given to the stick which held the stock of spinning fibres all the world over (fig. 95).

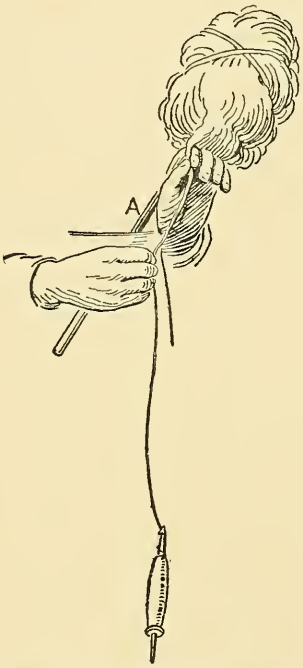
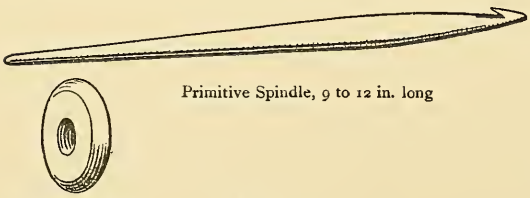


Fig. 95.—The Spindle revolving and twisting the Wool

A, Distaff, put through the Waistbelt.

Associated with the distaff we always have the spindle (fig. 96). From ancient description it seems to have been originally a cone of stone, with a nick or cleft in the side, to form a catch for the spun fibres. That the spindle must have been of some weight we know from its use. When the spinner had drawn out a short length of thread, she fastened it round the head of the spindle and hung the heavy cone by the thread, giving it a rotating motion to help the twining of her fingers. The revolving weight further drawing out and twisting the thread, it descended to the ground; then the spinner took it up and wound the spun thread upon it. In course of time the spindle was made longer and slenderer, to spin a finer and longer thread, and to counterbalance the lack of proportionate weight a lump of clay or block of lead, or other heavy substance was fixed on the end of the spindle. Designed at first merely to give steadiness and momentum to the spindle, this weight in time came to have another function. Spinners discovered that weights worn with the fingers into a rounded shape gave better results than new weights, and in consequence



Primitive Spindle, 9 to 12 in. long

Whorl or Weight

Fig. 96

thought it better to make them round. The round weight or whorl became a new agent, greatly assisting to lighten the labour of the spinner. With a single twirl the little wheel at the bottom of the spindle carried it right to the ground, completing a length in that easy manner. Thus by gradual degrees the distaff, the spindle, and the whorl were evolved. The spinner's tools were in this stage of development before the time of Catullus, whose vivid description has been translated thus:—

> "The loaded distaff in the left hand placed,
> With spongy coils of snow-white wool was graced;
> From these the right hand lengthy fibres drew,
> Which into thread 'neath nimble fingers grew.
> At intervals a gentle touch was given,
> By which the twirling whorl was onward driven;
> Then, when the sinking spindle reached the ground,
> The new-made thread around the spire was wound,
> Until the clasp within the nipping cleft
> Held fast the newly finished length of weft."

In that form the spindle remained for many centuries. Even at this hour, and in the highest forms of spinning machines, the straight spire and whorl are to be seen, though improved in many respects.

The Spinning Wheel.—Leaving the spindle for the moment, we turn to another instrument which was of no small importance in the history of spinning. While the spinners of western Europe were content to impart the twist to the thread and the twirl to the spindle by their own energy, aided by the whorl, their compeers of the East had devised mechanical aids. Hindu, or it may be Chinese, genius perceived the mechanical possibilities of the spindle. Laying it horizontally, with the ends running freely in bearings, the spinner obtained a steady motion for the spindle without the trouble of holding it. Propulsion of the spindle was imparted by sending round the whorl, which, of course, was retained. Next, some man conceived the notion of contriving a means of driving the spindle. He stuck five or more sticks into the body of a round log, at right angles to the length of the log and in the same straight line with each other, forming a ring on the log. On the ends of the radiating sticks he made a deep groove; on the whorl at the end of the spindle he made a corresponding groove; then between them he stretched an endless cord; the log, by supposition, being

also hung on bearings. Now by turning the circle of spokes round the spinner could drive the spindle at a very high rate of speed. The whorl being so much smaller than the circle of spokes round which the driving band was placed, and the band travelling at the same speed round both, the whorl must revolve at a much higher speed than the circle of spokes.

We are not called upon to discuss the marvellously potent mechanical principle exhibited in the rude structure of the early form of the spinning wheel. The principle, however, must be clearly

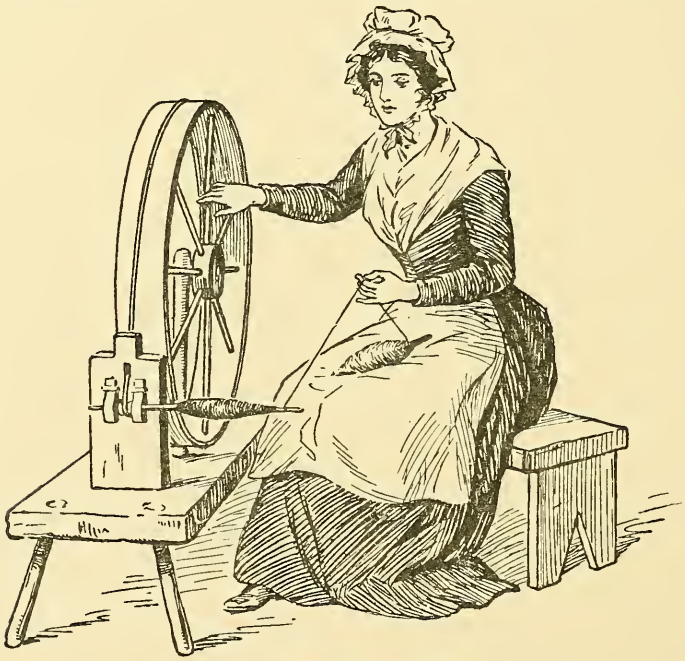


Fig. 97.—Primitive Spinning Wheel

understood if the construction of the spinning machines is to be comprehended. The simplest way is to express both circumferences in lengths. Suppose the circumference of the whorl to be 2 in. and the circumference of the spokes to be 36 in.; it follows that to travel the same distance on the whorl as it does on the spokes in a single revolution, the band must go round the whorl 18 times. That is to say, the spindle is driven 18 times quicker than the spoke wheel. For one thing, the saving in labour by this simple expedient is enormous; for a single twirl of the spokes we obtain a very large number of revolutions of the spindle.

The band round the spokes next suggested a permanent and

fixed basis between the spokes, to give the band a better hold and add to the stability of the spokes. The result was a wheel. It may be that the wheel, the most magical of all mechanical agents, was discovered otherwise than by the early inventors of textile tools; but we have here, in short compass, a natural history of the wheel. More than that, the pulley, the driving belt, and the shaft are all contained in embryo, but in actual working order, in the first rude spinning wheel.

The native of tropical Asia has seldom turned with desire to the north-west; no southern sword has glittered in the light of the northern sun; the dusky traders have seldom sought riches among the fair inhabitants of temperate climes. The tide of life, during the historical period at least, has flowed the other way. For that reason the industrial arts and appliances of the East have but slowly travelled westwards. Though the Hindus and the Chinese and other races of the far East have known the spinning wheel for many thousands of years, Europeans remained ignorant of the appliance till late in the fourteenth century of the Christian era. More remarkable still is the fact that up till the close of the eighteenth century the "rock and spindle" were in common use among the inhabitants of many districts of northern Europe. In the south of Europe, however, the intercourse of the nations with those of the East was fairly close and constant, and it was through Greece, Italy, and Spain that the arts and crafts of the East spread to the West. We have no record of the advent of the spinning wheel into the centres of Western civilization, but we are led to infer that it first came as the personal property of some Arabian or Moorish princess whose male relatives had conquered the south of Spain. For a long time the contrivance was the cherished plaything and useful toy of royal and noble ladies in the south of the Continent, and esteemed by the populace as a magical thing round which were woven mysteries and fairy tales.

It was not till near the close of the fifteenth century that the spinning wheel became industrial. At that time the spinners and weavers of Germany, Belgium, and the Netherlands, breaking free from the enfeebled grasp of a tyrannous feudalism, became rich and prosperous, enlarging greatly their productive powers and their trade. The strong demand for yarns of flax and wool brought the spinning wheel down from the palaces of the aristocracy into the humbler homes of the workers.

As it appeared first in Western industry, the spinning wheel was a rude and simple contrivance. A long three-legged stool formed the base, in which two posts were fixed to hold the wheel. About 3 ft. in diameter, with a plain broad rim, and small shaft in the middle of the axle block, the wheel was hung between the posts, which were cleft by deep grooves for holding the ends of the shaft. At the other end of the stool a pair of smaller posts held the horizontal spindle, with its grooved whorl set midway between the bearings, the length of the spindle projecting out in front. The endless driving cord was put round the rim of the wheel and the whorl of the spindle.

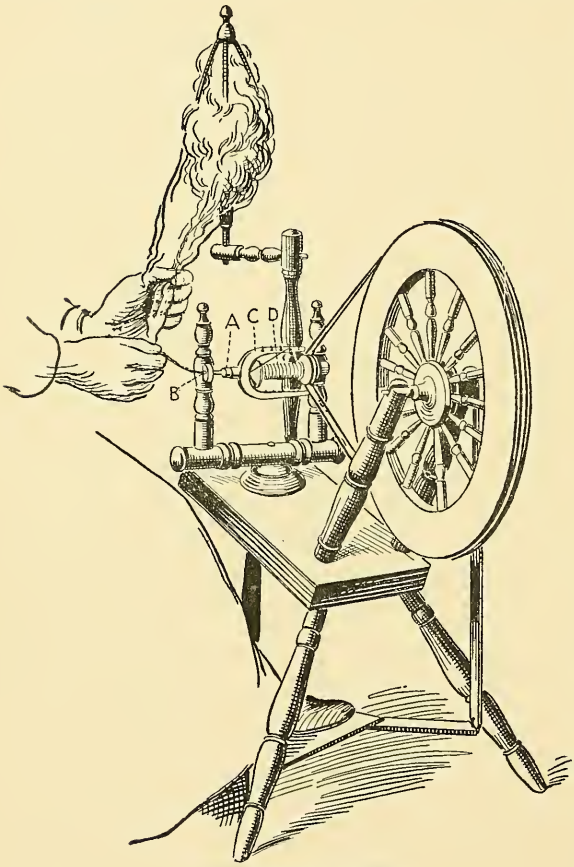


Fig. 98.—Saxony Wheel

A, Spindle. B, Eye of Needle. C, Flyer. D, Bobbin.

Rude as the wheel was, the spinner was not more cultured, if we may judge from her method. Holding the mass of prepared wool in her lap, she picked out the thickness of fibres required, brought the ends within touch of the point of the spindle, and with a blow of her hand on the spokes of the wheel sent it round. The revolution of the spindle driven by the wheel drew the fibres, and would, if allowed, have wound them round itself; but the spinner's aim was not then winding; she had first to make her thread. Keeping the fibres on the point of the spindle, and thus converting the revolution of the spindle into a twisting motion, she drew the fibres out between finger and thumb, regulating the thickness of the thread. When a

length of thread was formed, the spinner wound the thread on the spindle.

The citizens of Nuremberg claim the honour of having introduced the spinning wheel into industry. About 1533, three years later than the supposed date of the Nuremberg invention, another and improved wheel was invented in Brunswick by an inventor whose name is lost. The most notable feature of this wheel was the attachment of a treadle and crank to the axle of the wheel, by which the spinner could drive with her feet, leaving both hands free for the management of the yarn.

By far the most important and ingenious spinning wheel, however, came out of Leipzig about 1555. Designed originally for spinning flax, the machine was adapted for wool and cotton before it was superseded by the spinning frames. It is to the head of the Saxony wheel (fig. 98), as it was called, that we must direct our attention first, because there are features which gave it special distinction (fig. 99). Some of these wheels had a rock or distaff fixed close to the head, and others required a separate distaff; but that is of little moment.

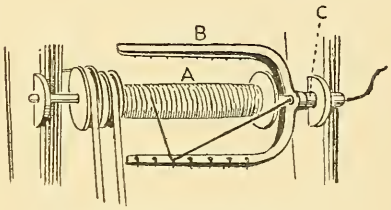


Fig. 99.—Saxony Spindle and Flyer

A, Bobbin. B, Flyer. C, Spindle.

The bobbin and spindle are hung in the head frame, the whorl of the spindle and the groove flange of the bobbin acting as pulleys in no way different from the Brunswick wheel. But on the top of the spindle the head of a two-pronged fork is fixed, the head at right angles with the spindle and the bent prongs extending parallel with both bobbin and spindle. This is the flyer, famous in spinning. Could the inventor of this contrivance be known, his name would rank with those of the greatest inventors. The head of the flyer is hollow, like a tube, and on the outer sides of both legs small metal hooks are set. In early times the flyer was a reed cunningly bent; but latterly it was made of wood or metal. On the wheel, driven by treadle and crank, a double groove is made, one for the band of the spindle and one for the bobbin band.

The spinner of linen threads hung her prepared flax on the distaff to the left of the spindle and flyer, and from it drew such a number of fibres as were needed to make the thickness of her thread. Twisting them with wet fingers, she led the formed end through the hollow tube in the head of the flyer, bringing it out on the leg of the

fork, threading it through one of the guide hooks on the leg, and twisting it round the barrel of the bobbin. Now she starts the spinning wheel. Revolving rapidly, the flyer draws and twists the flax from the fingers of the spinner, while the bobbin, running at a higher rate, winds the spun thread round itself. Thus in one operation the thread is spun and wound continuously.

Flax, being a large and strong fibre, could be spun in this direct manner; but cardings of wool and cotton could not be converted into thread by that method. The necessary tension would pull the fibres asunder, the spinning action defeating itself. We have not been able to trace an instance in which the Saxony wheel was used for the purpose of making cotton or wool rovings, that is, for making thread direct from the cardings. The woollen-yarn spinners never got beyond the common or Brunswick wheel, employing it first for the production of rovings with scarcely any twist, and then twisting and winding the rovings upon it. Spinners of worsted and cotton yarns had adopted a very efficient system before the advent of the factory, though hand-spun cottons were admittedly too weak for warp yarns. Under the system indicated the rovings were spun and wound on the plain wheel, and then the rovings were converted into thread on the Saxony wheel. Sometimes the poorer spinners confined themselves to making rovings, whilst the more fortunate possessors of a Saxony wheel spun yarns. In many families both wheels were kept, one member of the family making the rovings on the plain wheel and passing on the spools to another, who spun them with the finer wheel.

Primitive methods of spinning and old Brunswick and Saxony spinning wheels are still to be seen in regions of the British Isles and of the Continent remote from the railways, the cities, and the rushing currents of swiftly developing civilization. Even in London, in the Glasgow district, and near most of the great centres of high civilization, one form of the old spinning wheel still survives. It is the spooling or pirn wheel, employed in winding the yarns on spools, pirns, or cops for the hand-loom weavers. The wheel retains its shape; but instead of the distaff we have the swifts, which hold the skeins of yarn extended for unreeling, and a bobbin is always on the spindle. From the tall standard a pair of revolving barrels extend horizontally, the upper one being movable and fixed in place by a wooden screw. The hank of yarn is hung on the barrels, and the top barrel is moved into the position which stretches the

hank to the tension required. The winder places a spool on the spindle and puts an end from the hank round it. With hand or foot she sets the wheel going. As the spool revolves it draws the thread round itself, the hank of yarn on the lightly running barrels yielding readily to the draw. With her fingers the winder guides the thread along the spool, distributing it in even rounds, and forming a neat cone at the top. When the spool is filled it is taken from the spindle and an empty one put in place. Spool winding has been made mechanical and also more accurate.

Analysis of Hand Spinning. — Before a handicraft industry can be made mechanical, the labour process must be disintegrated, broken up, analysed. With the sagacity of genius Adam Smith fixed on the division of labour as the basis of modern political economy, the beginning of capitalist society. So long as the handicraft was a single operation, or series of operations, performed by one man, the machine had little opportunity of entrance, because the intelligent volition which passes from one independent operation to another is not contained in machinery, however cunningly constructed. But the growth of an industry brings on disintegration of the labour process. Instead of many workers being employed in carrying through the whole operation from start to finish, a group of workers is put to each division of the process; the division is then further broken up into small details and a workman given the single detail as his part in the labour. It is generally when an industry or craft has arrived at this stage that the machine comes into existence; the single detail is easily performed mechanically. Sometimes machines enter industries in other ways, as tools or aids, for example, and the change from tool to machine is effected by applying steam or other motive power.

We cannot enter further into the general subject of the mechanical displacement of hand labour. We have noted in our brief survey of the development of spinning the division-of-labour principle creeping into what was practically a domestic employment. Fundamentally, spinning is itself a mere detail of the great process of cloth manufacture; but that stage of textile manufacture has long passed away. Spinning had taken its place definitely among human occupations some time before the beginning of history. We refer now to the breaking up of the spinning process itself. When the idea of spinning the cardings into rovings occurred, the disintegration of the spinner's craft had begun. For in the formation of rovings,

as understood by the old-time spinners, doubling and drawing were the main aims; the subsequent process combined drawing, twisting, and winding, or spinning proper. Upon the hint, variously conveyed in different branches of textile manufacture, indicated by the separable details in the spinning operation, mechanical invention was based.

As practised immediately before the invention of roller drawing by Paul and Wyatt, and the spinning jenny by Hargreaves, the spinning process showed itself capable of being divided into several operations. Observing the spinner at work, we see her drawing the carded wool, flax, or cotton from the distaff and winding it on the spindle or bobbin, pressing and rounding it between finger and thumb, to give consistency to the drawn-out thread. The product wound on the bobbin is a soft roving, almost devoid of twist, resembling closely the slubbings of the present day. The pressing and regulating pull of the spinner's fingers is an important agency which was not imitated without some trouble. As we shall see, the absence of the sensitive touch was compensated for by the device of doubling. Next, the soft roving is to be drawn and firmly twisted into a consistent thread. Supposing that our spinner had only the plain wheel to work with, she was compelled to use the point of the spindle for drawing and twisting a length of the thread, and by releasing the drawing tension let the spindle wind the thread spun on to the bobbin. That this practice was very general the spinning mule bears witness, for the action of that wonderful contrivance is to draw out with an outward drawing motion and wind on the spun thread by a returning motion. While twisting her roving it was quite within the power of the spinner to draw it also, thinning and spinning the thread, because every twist added to the tensile strength of the yarn and gave opportunity for severe attenuation. If this operation is to become mechanical, therefore, some means of drawing as well as twisting and winding must be in the machine or machines.

On the other hand, if we suppose the roving spinner to be possessed of a Saxony wheel, the operation approaches more nearly to the mechanical. In fact, the flyer and spindle has become an integral part of spinning machinery almost unchanged; but here also we observe the drawing and doubling action of the spinner's fingers while the flyer performs the twisting and winding operations. In connection with the winding of the spun thread on the bobbin, another point may be observed. On the plain wheel the fingers of the spinner guide the thread on to the bobbin, filling it up in regular rounds under

the eye of the operator; but the flyer does not allow such an operation to be performed, and the difficulty is overcome by the small hooks on the legs of the flyer. Every now and then the spinner shifted the thread from one guide hook to another, so as to fill the whole bobbin in regular rounds.

The steps in the spinning process are drawing, doubling, twisting, and winding; and for each one of these details there are different sets of machines in most of the textile industries. Some branches of manufacture require to carry the drawing operation to great refinement; others scarcely detail the operation at all. Again, the doubling process is of importance in several industries, and in one or two others not at all. Twisting or spinning proper is necessary in all yarn manufacture, but the kind and degree of twist varies with the requirements of various yarns. By closely examining the root principles and rudimentary beginnings of processes so diverse and complex, we are enabled to understand what might otherwise be incomprehensible. In by far the majority of instances complexity is merely repetition of simple operations.

CHAPTER II

Drawing and Doubling

Textile Drawing.—The aim of the spinner of textile yarns is to produce a fine thread from the thick sliver; the sliver is his raw material and the thread his product. If the spinner's work were only thinning and elongation of slivers he would now be in the ranks of the unemployed; that work could be done by automatic machines. But the qualities of yarns are subtle and numerous; the weavers of cloths and laces, the makers of threads and ropes, demand yarns of uniform and definite quality. Apart from the soundness, roughness, smoothness, fragility, tenderness, lustre, dullness, or other attributes of the fibres composing them, all textile yarns are measured by the length of thread contained in a given weight. The units of measurement vary widely, but the method is common. In the cotton industry of this country, for example, the unit of length is the hank of 840 yd. and the unit of weight is 1 lb. Cotton yarns are classified according to the number of hanks contained in the pound. Ten hanks in the pound is 10 s, twenty hanks 20 s, a hundred hanks 100 s, and so

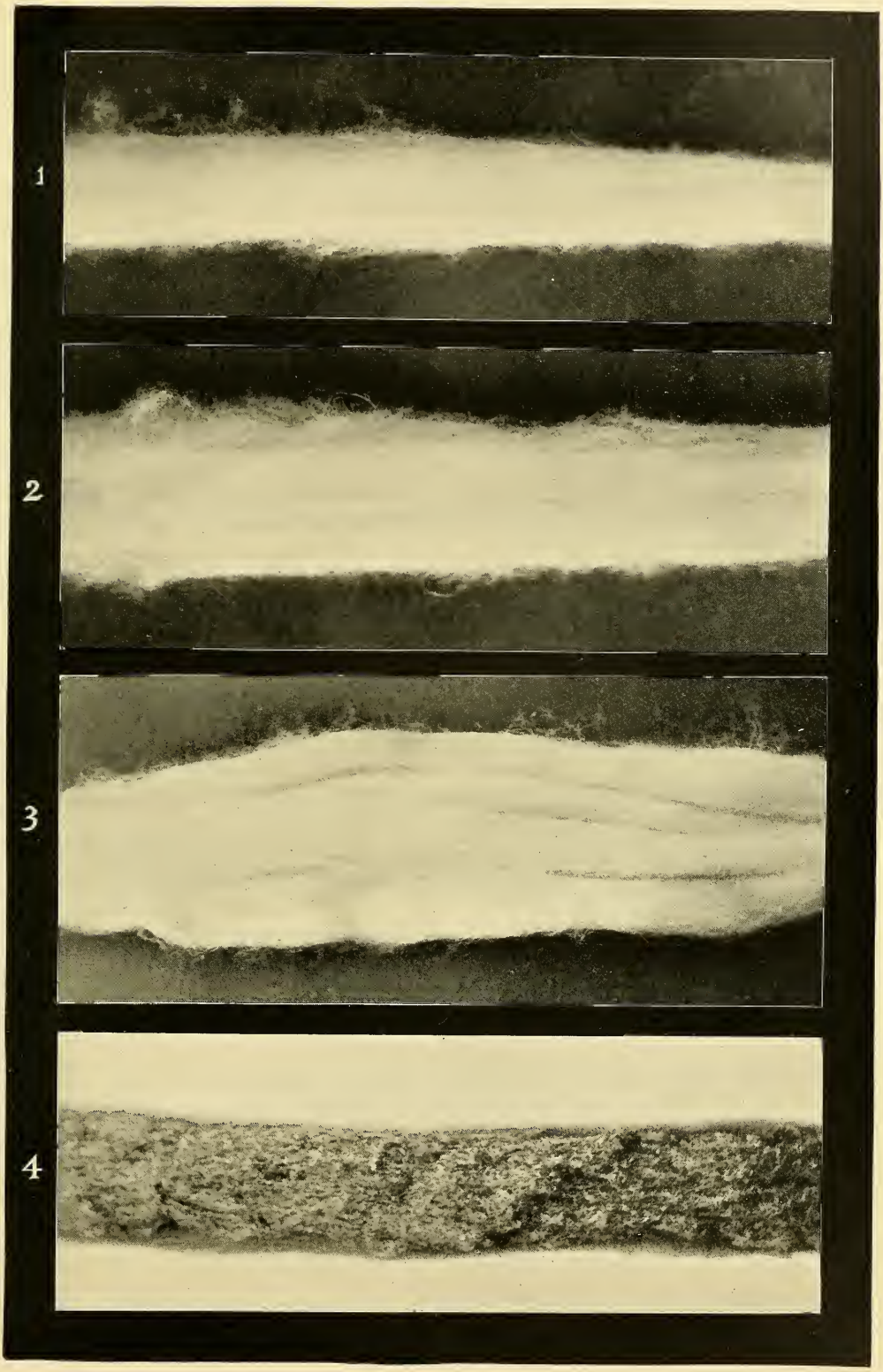
on. If the spinner sets out with the object of producing 24 s count of cotton, every yard of the product must be as nearly as possible of equal weight, and each hank must weigh one-twentyfourth of a pound. At another time it may be necessary to spin the same kind of cotton into 26 s or 22 s. The drawing of the sliver is therefore a very delicate operation, involving minute and accurate calculations and fine adjustments of mechanical appliances.

We have seen that the drawing of the thread on the spinning wheel was done by the fingers of the spinner. Hand spinners acquired a very fine sense of touch; skilled workers could detect the slightest change in the weight and thickness of a thread. If the roving was too thin, the deft fingers drew forward the fibres more rapidly; if too thick, the spinner drew out more swiftly or held the fibres back. When the inventor sought to make drawing frames, he was required to find a substitute for the intelligence and fine touch of the spinner. No machine can be endowed with vital intelligence, but analysis of the hand spinner's drawing shows that it is the rapidity of the action which demands intelligence. If we are content with a very little at a time the need for intelligent manipulation is obviated. But the inequalities in the sliver are not taken away, even though we grade our successive drawings ever so finely. To meet this objection another device has been adopted. No two slivers are wholly weak at similar points; it is conceivable that the combination of several will produce a perfectly even sliver, the weak parts of the one being made up in the strength of the others; the thicknesses of the one being met by the slenderness of another.

Hence the universal practice of doubling slivers at the drawing frames. It is another example of the principle of combining differences to produce an average of uniform quality.

Various Slivers.—Every fibre has its own sliver, and the slivers of each fibre are of varied weight and thickness. Comparison of the different slivers is instructive. Examining the jute sliver, we see how nearly perfect it has been made. The large fibres lie evenly together, though here and there short and long mingle. No close and elaborate drawing is necessary for jute.

Flax slivers vary in weight; any selected specimen closely resembles a tress of fine fair hair. The component fibres are long and lie evenly. But when closely compared, the flax slivers are seen to be imperfect in a very important quality. Regularity in thickness is seldom found in the flax sliver, owing to the large margin of difference between



SLIVERS.—I

1, Cotton. 2, Carded Southdown Wool. 3, Combed Southdown Wool.
4, Carded Grey Wool.

the shortest and the longest fibres. The alternation of weakness and strength thus produced gives much trouble in the drawing, and entails much anxiety on the worker.

The large variety of hemp slivers may be fitly represented by the manila. Being generally a rope sliver, it is drawn very smartly on the gilling machines.

The sliver of ramie is very smooth, lustrous, and beautifully regular. This fibre shows to best advantage in the sliver form, and seems to promise better results than have been realized in the spinning as yet. Long and hairlike in filament, the ramie sliver draws easily.

In spite of the rigorous refining of the wool-combing machines the sliver designed for worsted shows many defects in the eyes of the spinner. The fibres vary in length, cross and mingle irregularly, and manifest various erratic tendencies; the slivers are thin and thick at intervals in their own length, and the differences between one sliver and another are too patent to be ignored. The essential quality of a worsted thread is evenness of texture; to obtain this quality we must place the fibres as nearly parallel as possible. Worsted drawing is therefore a very delicate and elaborate process, involving many and closely graded operations.

The woollen sliver has been made almost a thread in the condenser, and hardly comes within our view at present.

The cotton sliver is comparatively a fine product, but it is the least fitted for what is required of it. The fine teeth of the carder have drawn the fibres in parallel lines; but some of the slender filaments have been doubled, instead of being stretched to full length. Between the doffing knife and the sliver-forming apparatus the harmony is not perfect, and thick and thin slivers is the result. Compared with the other fibres we have viewed, cotton is very short and very fine; the sliver is thick, and yet requires to be drawn into the finest of threads. Cotton drawing is therefore a long and difficult process. To make up for the inequalities in the slivers a complex system of doubling is necessary, the number of possible variations being the measure of the number of doublings needed to make an average.

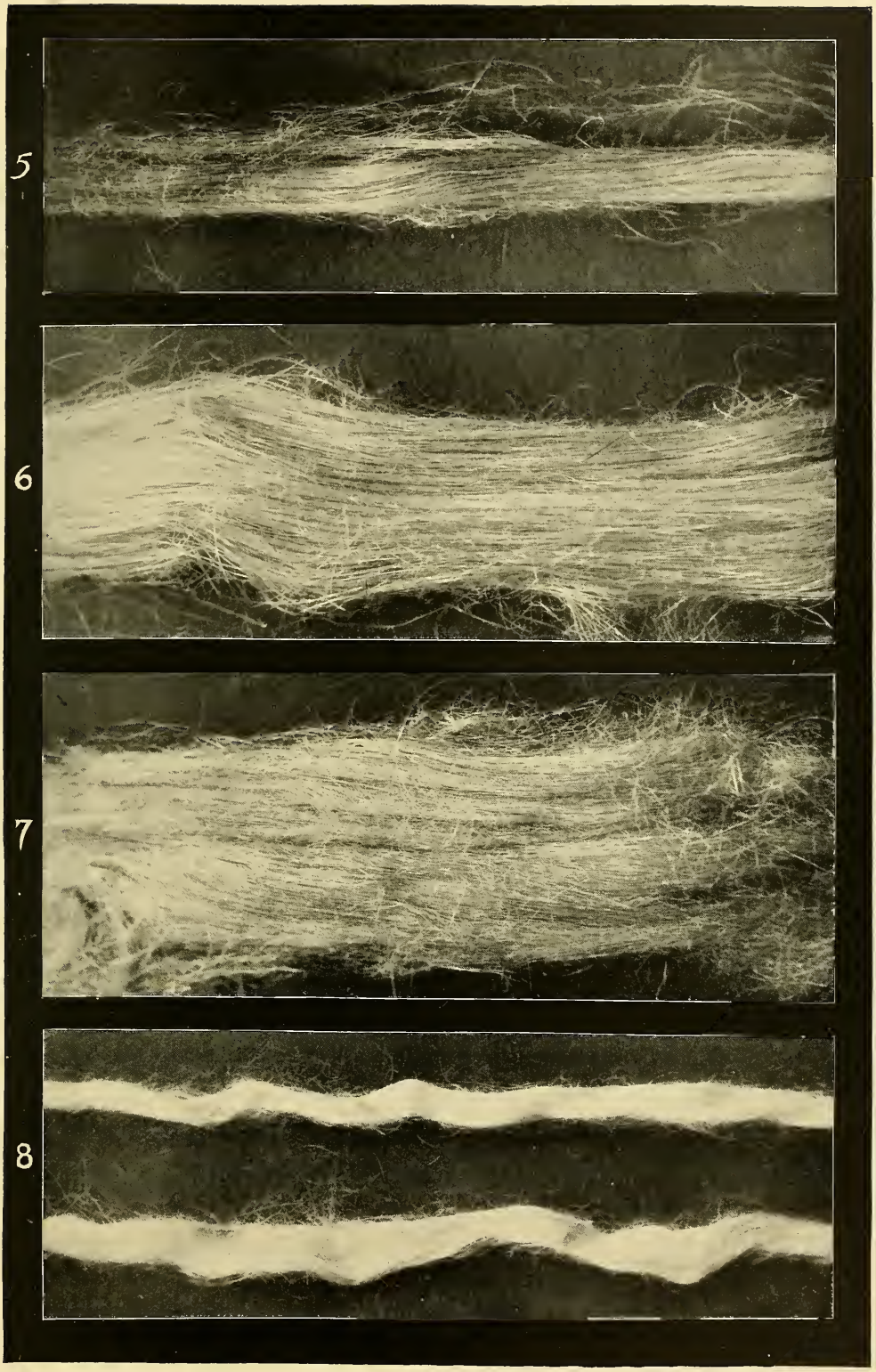
Choice of Drawing Tools.—In the preparation of fibres we have seen two kinds of tool employed in pulling them apart and stretching them to full length. The one is some form of comb and the other is a succession of pairs of rollers, each successive pair running at accelerated speed. In the carding and combing machines both tools have been seen at work; but these machines deal with masses of

material, and now we have a single rope to manipulate. All through textile manufacture a difference of material generally requires variation in the tools.

The fibres mentioned can be classified in three divisions: those which are thick and long, such as flax, hemp, and jute; those which are long and fine, as the various combing wools; those which are short and fine, viz. all classes of cottons. Having a thick and long fibre, we may continue to use the gilling machine, with its successive combs. A certain space must intervene between one faller gill and another; the gill points can never be set so closely that a very fine fibre might not escape them; but both these facts favour the long and thick fibres. Were we to attempt to work hemp or flax too finely, we should break them into dust. The firm grip of the shortly divided gill combs and their closely set needles would break up the fibres transversely and longitudinally.

The fine and long hairs of worsted wools do not so decisively favour the gilling machine. The fibres are long, but their fineness partially defeats the gill points, no matter how closely set. In consequence a series of compromises have been adopted in worsted drawing between the gill and the rollers of differentiated speeds. Worsted drawing can hardly be said to have finally settled into a system which is universally accepted. In general the gilling, so elaborated before the combing, is resumed with still greater elaboration; but the process is varied very considerably.

Cotton was the material which presented the greatest problem to the inventor of drawing machines. As we have seen, even the most closely set card clothing has failed to separate perfectly every one of the fine fibres from every other. In addition, the average length of the commonest of cotton is not more than an inch, and the variations in the lengths of the fibres are proportionately large. The eighth of an inch is not a large space, but when that is one-fifth of the total length of the whole it assumes an aspect of importance. With those factors to consider, the cotton spinners had perforce to await the slow performance of the hand spinners long after the need for some kind of machine had grown clamant. The problem was finally solved by the invention of the roller drawing frame. Having a continuous surface, the rollers evade the difficulty presented by the fineness of the cotton fibres; being capable of nipping a length equal to one-half their circumference, the shortness of cotton could hardly preclude their use. If, for example, a cotton fibre were only ½ in. long, by employ-



SLIVERS.—II

5, Fine Flax Sliver. 6, Hemp Sliver. 7, Carded Jute.
8, Carded Ramie (bleached and unbleached).

ing drawing rollers 1 in. in circumference, and setting the pairs close together, the second pair would grip the fibre before the first had quitted hold. This, as we shall see, is not necessary, but the extreme case illustrates the value of the principle of roller drawing.

The Cotton-drawing Frame.—The merit of conceiving the idea of drawing cotton by means of rollers is doubtfully ascribed to Lewis Paul, the son of a French refugee, who carried on business as a druggist in St. Paul's Churchyard, London. In 1738 Paul, in conjunction with John Wyatt, took out a specification of which the

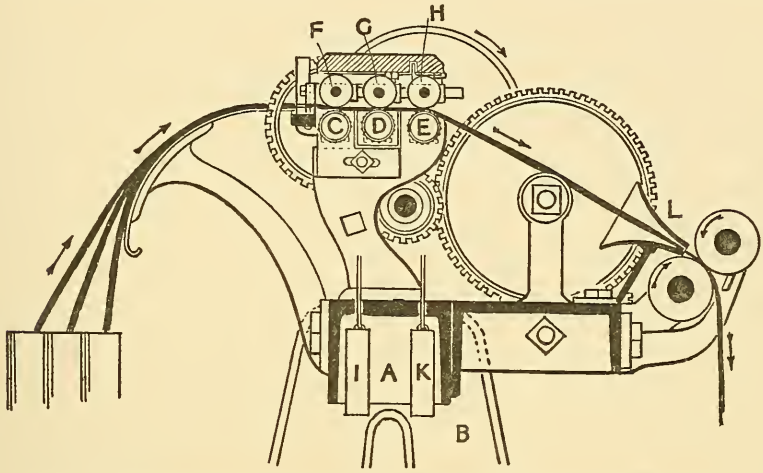


Fig. 100.—Cross Section showing Principal Working Parts of Arkwright's Drawing Frame

A, Roller beam, which is supported on the frame B of the machine. C, D, E, Fluted rollers, of which C is fixed; D and E are adjustable. F, G, H, Upper rollers, kept in contact with C D E by the weights I, K. L, Funnel, receiving slivers from two adjacent sets of rollers.

following is an abstract: "The wool or cotton being thus prepared (carded and formed into a sliver), one end of the mass, rope, thread, or sliver is put betwixt a pair of rollers, cylinders, or cones, or some such movements, which, being twined round by their motion, draw in the raw mass of wool or cotton to be spun in proportion to the velocity given to such rollers, cylinders, or cones. A succession of the rollers, cylinders, or cones, moving proportionately faster than the first, draw the rope, thread, or sliver into any degree of fineness which may be required."

Through various causes, which it is not our present business to detail, Paul did not succeed in bringing his patent into successful operation. For thirty years the principle was laid aside and other methods of solving the problem of mechanical spinning were devised.

In 1768, however, Richard Arkwright brought out his patent for the water frame spinning machine, the principal feature of which was the employment of drawing rollers. The details of this machine may be passed over at present. When he set himself to organize the whole cotton factory Arkwright devised the separate drawing frame which it is our immediate business to consider. Arkwright cannot be credited with originating the drawing rollers, but he made them into a working machine. Another valuable idea, however, must be ascribed to him. Though so obvious to us, the notion of doubling slivers on the drawing

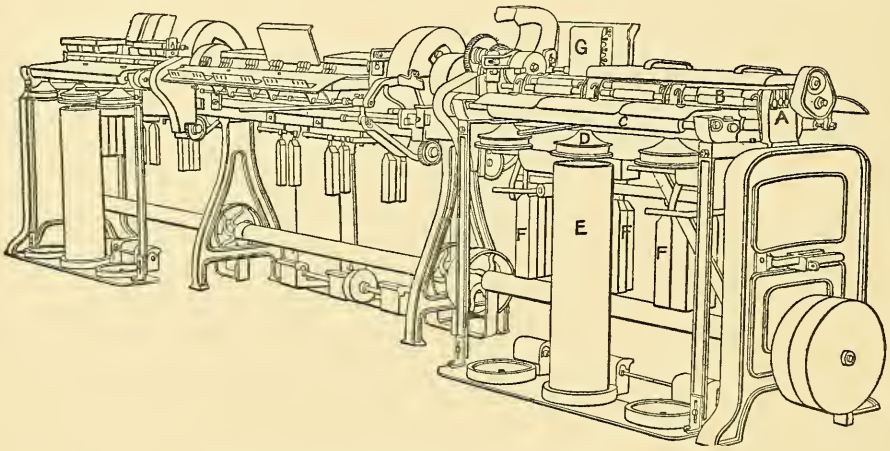


Fig. 101.—Drawing Frame (Messrs. Platt Bros. & Co., Ltd.)
A, Bearings of drawing rollers. B, Top and bottom rollers. C, Calender rollers. D, Coiler. E, Sliver can. F, Weights on rollers. G, Clearer (lifted).

frame or in the drawing process, to produce equal and uniform threads, had not been systematically adopted till Arkwright took it up. He had thoroughly grasped the division-of-labour principle, and instead of trying to devise machines which would carry through the spinning process by itself, he divided up the process and made one machine or more for each detail of every operation. Costly and tedious as the method seems, it has been triumphantly justified by results. The cotton factory is the most efficient productive organism devised by human intellect.

The Principle of the Drawing Frame.—In the main the principle of the roller drawing frame is simple. Four pairs of rollers are set on the same plane, the second pair in front of the first, the third pair in front of the second, the fourth pair in front of the third, at such distance as may be required. For the present the shape and character of the rollers may be left out of sight; the interaction of

the pairs is the matter of observation now. Suppose the four pairs of rollers properly adjusted to the average length of the fibres composing the sliver and all run at the same speed, what would the effect on the sliver be? No drawing effect could result, whatever other effects might occur. Alter the speed ratios of the pairs of

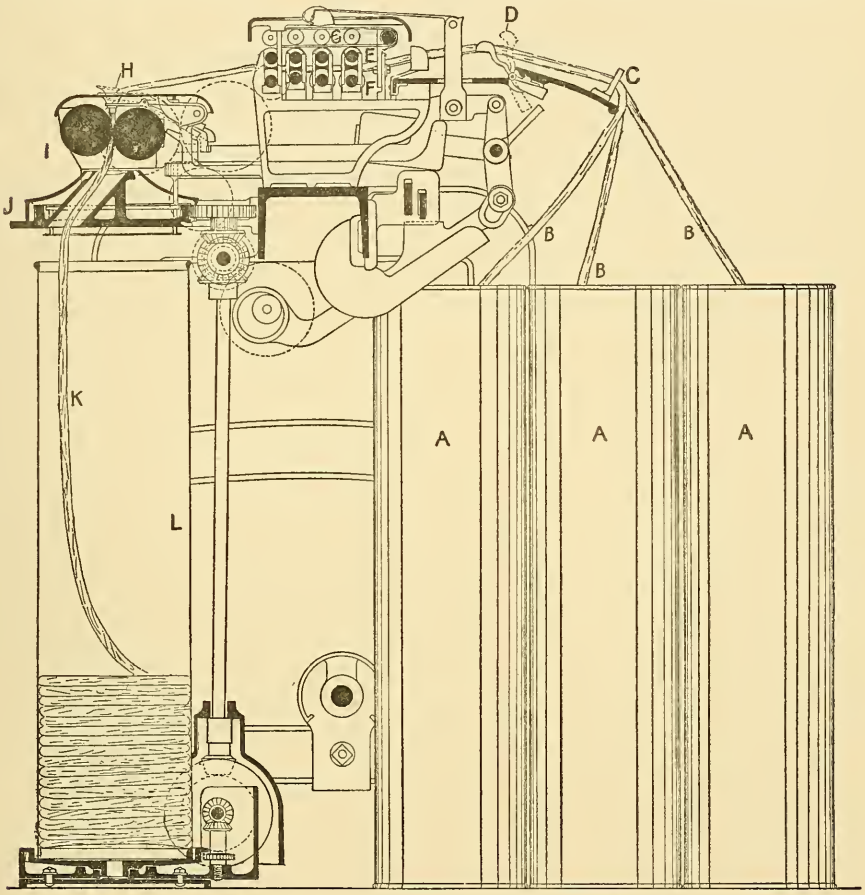


Fig. 102.—Section of Drawing Frame (Messrs. Platt Bros. & Co., Ltd.)

A A A, Sliver cans. B B B, Slivers. C, Gathering guide of slivers. D, Tumbler lever stop motion. E, Top drawing rollers. F, Bottom drawing rollers. G, Clearer apparatus. H, Trumpet-mouthed receiver of sliver. I, Calender rollers. J, Coiler disc. K, Drawn sliver. L, Finished-sliver can.

rollers, however, and an effect instantly becomes apparent. Say, for example, that the speed of the first pair of rollers is 1 ft. per minute, the second 2, the third 3, and the fourth 4; the sliver running through would be lengthened out four times; for every foot of sliver we would have 4 ft. after it had passed through those drawing rollers. With a fibre so short as cotton such rapidity of attenuation is im-

possible. Take an actual case. The ratios in drawing common counts of cotton are as follows: First pair, 1.00; second pair, 1.25; third, 1.75; fourth, 2.75. Here the acceleration of speed is gradual, the difference in speeds increasing from first to last. The first pair revolving one-fourth slower than the second, the sliver between them is drawn out one-fourth; the second pair of rollers allows the third pair to gain half a revolution in one, and the sliver is therefore further drawn out between them; the difference of speed ratio between the third and fourth is even greater, with a proportionate elongation of the sliver. In this instance for every 4 ft. in length of sliver we obtain 11 ft.

Doubling.—The sliver is a soft rope, and the cotton fibres are short. If the work of attenuation is carried too far it defeats the aim of the spinner. Having little tensile cohesion to begin with, the sliver will cease to hold together if attenuated without some compensating accession of strength. By putting two slivers together through the drawing frame the spinner at once doubles the strength of the drawn material. Other advantages have already been discovered in doubling. By combining slivers the percentages of irregularities are reduced and an average of uniformity gained. Doubling is therefore a very serviceable device for the worker on the drawing frames. To achieve the double purpose of strengthening the sliver, and bringing it to uniform quality, as many as eight slivers are combined on a drawing frame, and sometimes six. Before being accepted for further treatment the slivers are subjected to two, three, and up to four drawings, with doubling each time. For soft, spongy yarns the slivers are seldom drawn more than twice, but in the highest counts four drawings and doublings are needed. Even in the lowest grades of yarns the doublings are numerous. As a rule the slivers are put eight at a time through the drawing frame when two drawings only have to be given. Eight times eight are 64; that is to say, the finished sliver after two drawings contains a combination of so many slivers. In three drawings we obtain a sliver composed of 512 different slivers. In the drawing department of a famous fine-spinning cotton mill, the following formula is faithfully followed:—

$$\frac{8}{L}\ \frac{4}{L}\ \frac{7}{L}\ \frac{6}{L}\ \frac{6}{L} = 48{,}384 \text{ doublings.}$$

Doubling so complex is admittedly unnecessary if only the effort

after uniformity is considered, but the doubling must keep up a certain ratio with the drawing if the strength of the sliver is to be maintained.

Structure of the Drawing Frame. — The construction of some machines employed in textile manufacture concerns only the engineer and machine builder; but the cotton operative, or anyone desirous of understanding textile processes, has an interest in every part of the drawing frame. The work of the frame consists in feeding the slivers to the four pairs of rollers, drawing by the rollers, collecting the drawn slivers, and delivering. One drawing head is a complete machine, but the drawing frames may be made up of two, three, four, or six heads. Machinists are constantly changing and improving the forms of the frames, adding or altering parts, and other details, spurred thereto by the fact that no patent can be held by anyone for any roller-drawing appliance. In many details the newer machines differ from those with which most cotton operatives are familiar; but our chief concern is with the leading principles of the machines, and these do not alter much.

Drawing Rollers.—The frame most commonly employed has three heads of delivery, and this, for reasons which shall appear, has been selected for examination (fig. 101). As the most important section of the frame the drawing rollers claim first attention. Four shafts resting in bearings on the rollers beam extend the full length of the frame. On each shaft there are six corrugated bosses, two to each of the three heads. A short roller with two bosses sits upon every pair of corrugated bosses, the ends of the short roller being hung with weights. Top and bottom rollers form a pair, or, more properly, a head, composed of two pairs of bosses. In common language we should call these bosses rollers. As has been said, the bottom rollers are deeply fluted or corrugated; the top rollers are generally smooth on the surface and derive motion from the bottom rollers, upon which they are pressed by the weights.

Some changes have taken place in the form of the top rollers. In the oldest drawing frames, some of which are still working, the first two of the four top rollers were fluted; but it was considered by some that the deep corrugations broke the cotton fibres, and so the top rollers were leather-covered, to give a soft and firm grip. As the slivers being drawn and doubled pass between the bottom and top rollers the combination of leather and iron flutings would seem to promise the effect desired; but the leather coverings of the top rollers

are apt to become impregnated with oil and dirt. One factor, however, must not be omitted: when the sliver has been doubled and drawn several times it becomes firm and consistent, and too solid pressure might injure the fibres.

The bearings of the drawing rollers are movable, permitting a widening and narrowing of the spaces between the successive pairs. When we remember the various lengths of cotton fibres, and the drawing force exercised by the rollers, a provision of this sort is

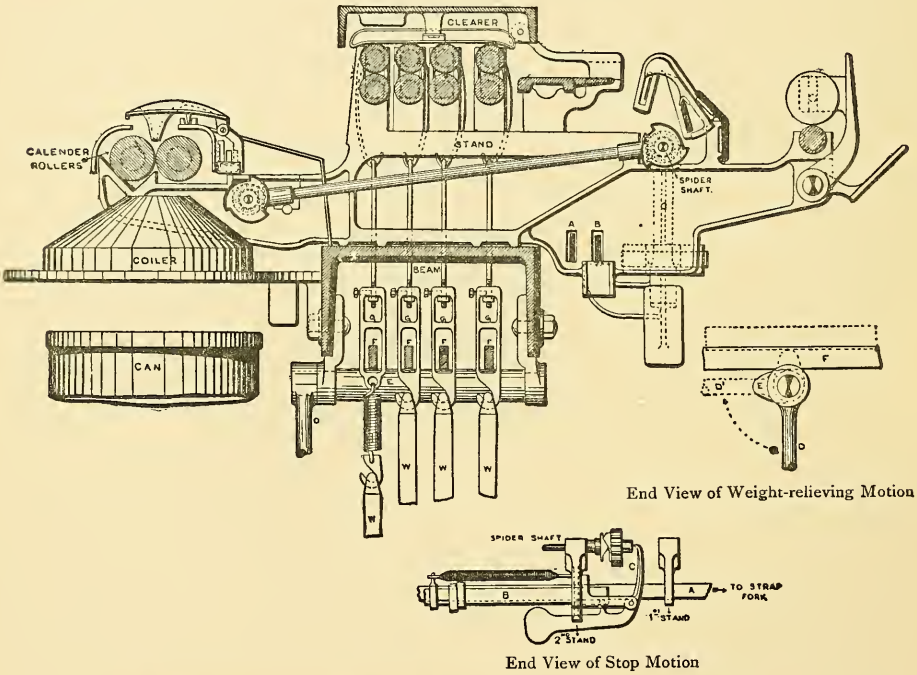


Fig. 103.—Section of Drawing Frame showing Stop Motion (John Hetherington & Sons)

seen to be needed, for the grip of the drawing rollers is firm and the draft is strong. A fibre gripped by the second pair of rollers before it has been released by the first stands a good chance of being torn in two. Nipping of the fibres is to be avoided as a serious evil. The smooth surface of the upper rollers allows a small measure of slip, and mixed fibres of varying lengths may be safely worked; but when the distance between the rollers is too short for the bulk of the fibres composing the sliver, nipping is sure to occur. If, on the other hand, the rollers are set too far apart, rupture of the sliver ensues. The latter evil is the worse; but we think it

a good practical rule to set the rollers wider than the average length of the fibres.

Clearers.—Drawing rollers do their work at the points of contact between upper and bottom rollers; in the operation they are apt to carry away some of the cotton, which accumulates on the top rollers especially. If allowed to remain, the waste would soon clog the rollers. The simplest form of clearer is a set of cloth-covered wooden bars placed in contact with the top rollers and the front drawing rollers; but these fixed clearers are themselves a source of trouble, requiring to be cleaned often by hand. Flannel-covered rollers fitted with doffing combs have also been adopted with some degree of success. Another device, called the "Ermen" clearer, is an end-

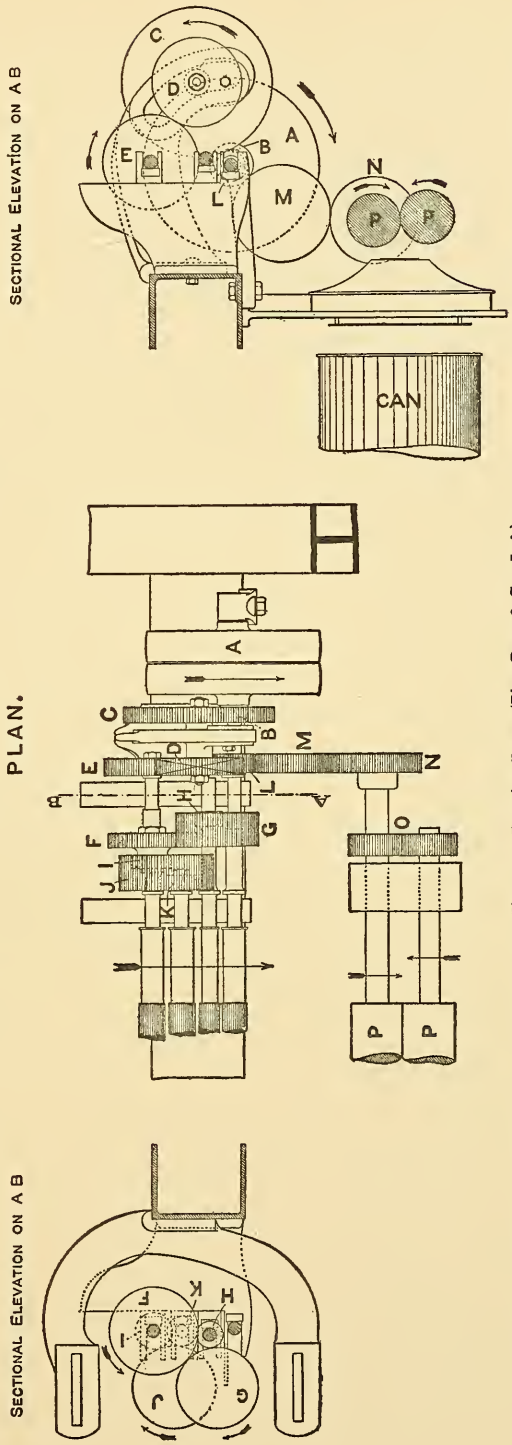


Fig. 104.—Drawing Frame (Platt Bros. & Co., Ltd.)

A, Front roller pulleys, 10 in. diameter. B, Front roller pinion, 18T. C, Crown wheel, 100T. D, Draft change wheel, 46T to 56T. E, Back roller wheel, 54T, 60T, or 66T. F, Wheel on back roller for driving and roller, 52T to 60T. G, Double carrier wheel, 56T. H, 2nd roller pinion, 20T to 22T. I, Back roller pinion for driving 3rd roller, 25T to 28T. J, Double carrier wheel, 56T. K, 3rd roller pinion, 22T to 22T. L, Front roller calender wheel, 18T or 20T. M, Carrier wheel, 44T. N, Calender wheel, 39T. O, Calender roller coupling wheels, 30T. P, Calender rollers, 3 in. diameter.

less band of felt stretched between two spiked rollers over the top rollers, with a fixed doffing comb fitted over it. The spiked rollers drive the felt round, being themselves attached to the drive of the frame, and the doffing knife cleans the felt as it comes round. An improved clearer which has proved very successful is thus described by the inventor:—

"This improvement is a combination of the stationary and the Ermen clearer. It is an exceedingly simple device, and entirely dispenses with gearing, while at the same time the contact between the flannel and the surface of the drawing rollers is at all times assured. Instead of causing the flannel to revolve by means of a spiked roller an additional comb is introduced. This hinges loosely to the front side of the arm which carries and works the stripping comb. As the latter recedes and strips the flannel of the waste fibres the front comb travels along with it, but the teeth therein ride loosely over the surface; on its return journey, however, the teeth enter the web of the flannel and give it a forward movement. In order that the action of the front or driving comb may not take place until the stripping comb is clear of the waste, a certain amount of play is given the former in its attachment to the reciprocating arm. By this arrangement the clearer flannel can be mounted in a frame capable of adjusting itself to the rollers—a feature in the stationary clearer which is not available in the Ermen arrangement."

Feed Arrangements.—The cans containing the slivers are ranged in rows behind the frame. Guide holes are closely set along the edge of the frame to prevent the sliver from being carried to the drawing rollers in a tangled condition. On the old frames the guide holes are merely arches of wire, but the newer frames have more ingenious devices. Eight slivers laid alongside occupy a wide space, and devices have been invented by which the slivers are fed in two rows, generally slotted plates, each top slot being in between two bottom ones. Besides concentrating the feed the appliance assists the single preventer. From the guide holes the slivers pass over the smooth, convex guide plate, the head of the tumbler stop-motion, and the hooks of the traverse guide, to the first of the pairs of drawing rollers, the back rollers as they are called.

Stop Motions.—As it came from the hands of the great inventors of the eighteenth century the drawing frame was a thoroughly efficient machine, so far as the drawing action itself went; but both in feed

and delivery there was room for improvement. Given plenty of time and a skilled operator the drawing frame produced good work; but competition called for higher and ever higher speeds, and the efficiency of operatives did not keep pace with the demand. One of the six or eight slivers might break or become exhausted, and the operative fail to observe it at the moment. The absence of a sliver from a drawing changed the whole character of the product. "Single", as the defect was named, caused much trouble. If not discovered in time it meant the waste of the whole of the sliver drawn during the interval; but that was not the worst evil. To avoid censure the operatives pieced up the sliver and sent it on, introducing a gross irregularity into the yarn which might only be detected after it had affected the work to a damaging extent.

Many attempted to introduce apparatus to prevent single. About the middle of the nineteenth century, however, the problem was successfully solved by James Smith of Deanston, Scotland. This remarkable man experimented in his mill, by the side of the waters of the River Teith, above the ruins of Doune Castle, till he had found an automatic stop motion for the drawing frame. Long after Smith died it was a tradition among the villagers of Deanston that when he conceived an idea he never ceased to work at it till his purpose was achieved. A touch of exaggeration may be allowed for, but the stop motion bears out the truth of the report in the main. It is an idea which could only have become practical through long, oft-repeated, and patient experiment. Smith's invention has long been superseded, but his idea is contained in all forms of stop motions.

Every firm of machine builders has its own special stop motion, and, of course, according to the catalogues, each one is superior to every other. To detail those mechanisms minutely would take us far, but the main principle of them all is easily understood. The instrument of all forms of stop motion is a spoon lever or tumbler, nicely balanced on a knife edge or pivot, the one point resting on the passing sliver and the other connected with rods and levers which act on the strap fork. Finely adjusted to the normal thickness of the sliver, the spoon lever tilts up at a sudden thickening, falls down at a quick attenuation of the sliver, and in both cases calls the stop-motion levers into action. This contrivance has been placed over the back of the drawing frame to regulate the feed, at the point of delivery to regulate the thickness of the sliver, and over the filling cans to preclude overflow. A broken sliver, a knot of waste from the clearer,

a failure among the drawing rollers, or any other accident calls one or other of the levers into action and stops the frame.

Electric Stop Motions.—After cautious experiment electricity, the subtlest of motive powers, has been applied to the stop motions of the drawing frame. A small magneto-electric battery, driven from the main shaft, is placed at the end of the frame, and from it rods or wires carry the current to the points at which the power is to act as stop motion. So long as the frame is working normally the circuit cannot be completed and the electric current does not act; but the coming together of the top and bottom drawing rollers, the too great elevation of the top rollers, the overbalancing of the front and back levers, complete the circuit and the electric current stops the frame.

Delivery Apparatus.—When the sliver issues again from the drawing rollers it comes in between a pair of calender rollers, by which it is compressed and delivered into the coiler of the sliver can below. Driven by pinions on a horizontal shaft, the coiler disc, with the funnel in the centre of its revolution, lays the sliver coil by coil in the can, which is at the same time revolving on the holder trays. On the outside of each tray is a ring of teeth into which works a spur wheel working into a bevel wheel on a driving shaft over the trays. This shaft is driven by an upright shaft receiving motion from a shaft conveniently placed near the roller beams.

Operating the Drawing Frame.—It is at the drawing frame the cotton-yarn spinner must begin to consider definitely what kind of thread he is going to produce. If the yarn desired is soft, open, and spongy, the drawing must not be carried too far. Wefts intended to spread are kept open and fleecy; warps of goods which are to be heavily sized have to be spongy in body. Drawing brings the fibres more and more closely together, therefore the oftener the slivers are drawn the closer the consistency of the sliver will be. In deciding what amount of drawing the sliver should be subjected to, the kind and quality of the cotton must be taken into account. Hard, rough cottons remain open and spongy after very severe drawing; soft, flexible, and fine cottons very readily harden and form a solid body of sliver under the drawing rollers. Taking the three great classes of cotton, the following may be taken as a standard:—

	Driving Shaft. Revs. per min.	Front Roller. Revs. per min.	Dia. F.R. Inches.
American ...	... 285	 350	..... $1\frac{3}{8}$
Egyptian ...	... 185	 275	..... $1\frac{1}{2}$
Sea-island ...	... 140	 210	..... $1\frac{1}{2}$

This, as will be obvious, only gives the differences which should be made on the drawing frames. The question of the number of drawings is not to be settled so simply. Another important factor enters into the calculation; the amount of draft on the rollers must be known before anything can be settled.

Draft.—The total draft of a drawing frame is the difference in the surface speeds of the front and back rollers. To find this it is only necessary to treat the whole as a train of wheels; multiply all the driven wheels together, all the drivers together, divide the one by the other, and the quotient will be the draft. But the second and third pairs of rollers are also to be adjusted, and we desire to know what is the draft between them, or between them and the front and back rollers. For the sake of simplicity let us take the fourth and third rollers as an example. Multiply the fourth roller wheel, the wheel driving the third roller, and the diameter of the third roller together for a divisor, and the wheel driven by the fourth roller wheel, the wheel on the third roller, and the diameter of the fourth roller, for a dividend, and the quotient will be the draft required. Thus, let the fourth roller have 20 teeth, and the wheel it drives 64 teeth, the wheel driving the third roller 42 teeth, that on the third roller 30 teeth, the diameter of the fourth roller $1\frac{3}{8}$ in. and the diameter of the third roller $1\frac{1}{8}$ in., then we are given this result:—

$$\frac{64 \times 30 \times 1\frac{3}{8}}{20 \times 42 \times 1\frac{1}{8}} = 2.8, \text{ the draft required.}$$

A simpler method may be taken from the diagrams of plan and sectional elevations of Messrs. Platt's drawing frame (fig. 104). There we see that the number of teeth on the pinion driving the third roller is 25, and that the number of teeth on the pinion driving the fourth roller is 20. Suppose the diameters of both to be the same, then by dividing the former by the latter we find the draft, which is, of course, $1\frac{1}{4}$.

By either of these methods the draft between any two pairs of rollers may be calculated.

To alter the draft the relative numbers of the teeth on the wheels are changed. The draft required being the known quantity, and the number of teeth on the roller to be changed the unknown, we put the former in the place of the latter, and the result will be the number of teeth required on the wheel.

Drawing-frame problems present themselves in many forms, and

the worker is constantly being met by questions which can best be solved by practical experiment. But experience has shown us how we ought to proceed in trying to find the answers to the more frequent difficulties which occur in work. The following formulæ should be useful:—

1. To find the count of the drawing, multiply the draft by the count of the carding, and divide by the number of ends up.

2. To find the weight of the drawing, multiply the weight of the carding by the number of ends up, and divide by the draft.

3. To find the draft, multiply the number of ends up by the count of the drawing, and divide by the count of the carding.

4. To find the count of the carding, multiply the number of ends up by the count of the drawing, and divide by the draft.

5. To find the change wheel to be put on, multiply the present count of the drawing by the change wheel on, and divide by the count of the drawing desired.

Summary.—When the cotton slivers are brought from the carding room to the drawing department the count of the carding and the character of the cotton are specially noted. The drawing master has his instructions, informing him what count and weight of drawing are to be produced. The cans are ranged in the number required for the amount of doubling necessary behind the frames; the drawing rollers are set to the average length of the fibres to avoid nipping; the wheels with the proper number of teeth are put on to make the draft required; the stop motions are adjusted; the receiving cans are put in place; finally, the drive is put on. From the cans the eight slivers run in through the guide holes, which gently push back the doubling slivers, as with sentient fingers, and let them through in a steady flow, to run over the smooth guide plate, over the delicate tumbler and through the hooks of the traverse guide into the grip of the back pair of rollers. From the back pair, sometimes called the feed rollers, the slivers, now being combined, are sent on to the second, third, and fourth pairs, each one feeding its successor, but with the restraint which produces the draft, and then the cotton passes between the calender rollers, which pass them on to the funnel of the revolving disc beneath which revolves the receiving can. During operations a sliver fails, or is licked up round a roller, or thins, or thickens, and the back stop motion or the preventer, or the front stop motion, sends the word along to the driving belt, which obediently knocks off, and causes the frame to cease moving.

The drawer repairs the fault, and the frame resumes working. Thus we obtain a drawn and doubled sliver of cotton. The whole operation is repeated as often as the scheme of the spinning master demands.

Worsted-wool Drawing. — Many who have sought to gain a thorough knowledge of worsted drawing complain that the machines and methods vary so much in practice as to baffle comprehension. Some sympathy is due to the complaint. No Arkwright has come to organize wool manufacture; for lack of a man of commanding genius the industry struggles to define itself. But the position has also its advantages; the wool industry still retains much of the freedom, flexibility, and artistic quality of handicraft. In all forms of handicraft the workman stamps his individuality on the thing he makes; it is good, bad, or indifferent according to the capability of the maker. Some measure of the same force still belongs to the wool manufacturer, though he employs power-driven machines. No one who has not handled wool cloths and yarns can imagine the almost infinite grades and shades of quality to be found in those commodities.

We believe that the scientists, the inventors, and the factory organizers have all some work before them in the various branches of wool manufacture, but a large measure of the evil, if evil it be, arises from the variety of fibre we class as wool. We can hardly hope to spin the fine, short wools of Saxony and Australia in the same way as the long wools of Lincoln and Kent; nor is it possible to obtain the soft, fleecy threads required for heavy worsteds so easily from the old English methods of drawing as from the French system recently introduced.

Progressive changes are bound to come, and approximate uniformity may confidently be expected. As a preliminary we propose to separate, in idea at least, the drawing operation, pure and simple, from those operations which combine twist with drawing. The successive stages in the process from this point onward are interesting, and specially worthy of careful observation. First, we have drawing and doubling; next, a little twisting is added on to the drawing, because the doubling ceases, and another means of keeping up the strength of the elongating thread must be adopted; then the amount of twist increases and the drawing decreases stage by stage, till, at the last, the relation between the two actions is reversed. When the twisting predominates over the drawing the operation is named spinning; the operations preceding are lumped together under the single

name of drawing. In practical work, names do not matter very much, but it is always better to make technical terms descriptive when that is possible. An intermediate term, therefore, should be invented to distinguish simple drawing from those operations into which the twisting or spinning action enters.

One very important reason for making the distinction between the first and simplest stage of what is collectively called drawing,

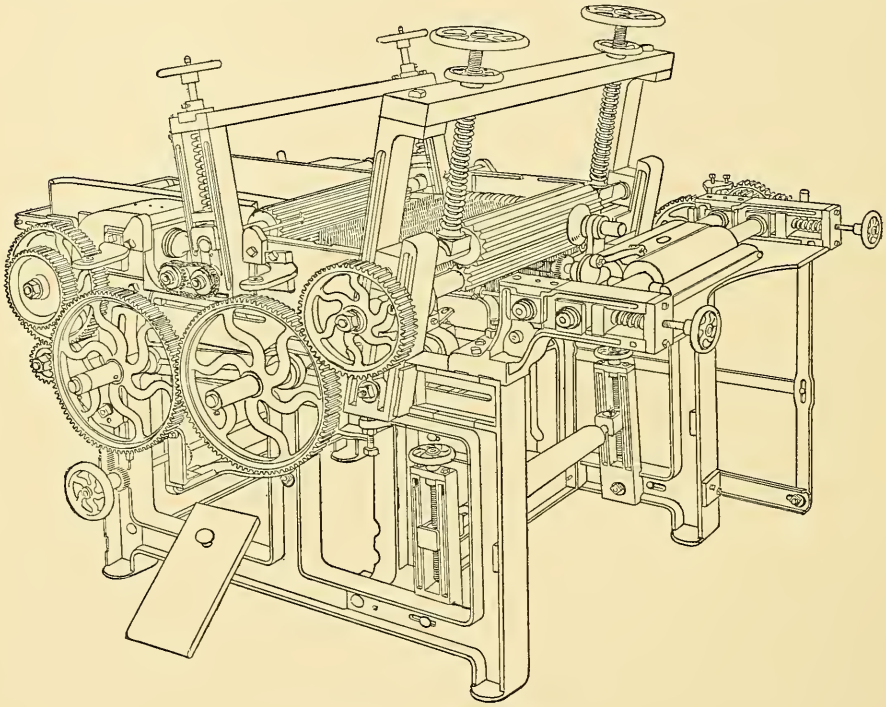


Fig. 105.—First Gilling Frame

and the stages succeeding, is the fact that a pair of wonderful tools, viz. the bobbin and flyer, are introduced in the latter stages. To treat the bobbin and flyer as mere accessories of the drawing frame is to underestimate their importance altogether. Those tools mark a distinct and fresh departure in the spinning process and should be separately considered.

Systems of Wool Drawing.—There are three systems of drawing employed by worsted spinners at the present day. These are the English, the French, and the roller systems. It is generally agreed that the English method is most suitable for drawing long wools into straight and even threads; the roller drawing frames are pre-

ferred for short wools; the French frames are most suitable for the production of yarns of an open and fleecy nature.

English Gilling Frame.—According to the English mode of drawing, the sliver, after it has come from the combing machine, is passed again through the gilling frame. Excepting that the slivers are finer, the first drawing operation is similar in every respect to the

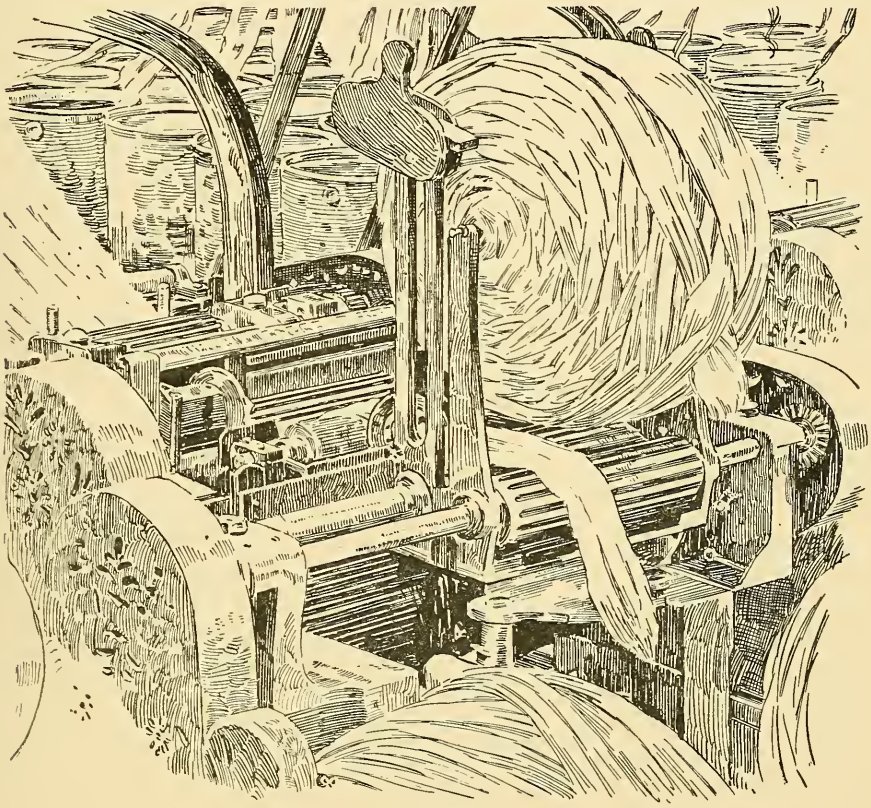


Fig. 106.—First Gilling Frame, showing Drawing Rollers

gilling which prepares the wool for the combing machines. Some small changes are to be observed on the machines, however, and should be noted. The bottom rollers of the gilling machines are leather-covered; on the drawing frames the bottom rollers are fluted and the top rollers covered with leather aprons. The difference is significant, and marks the advance which has been made. On the gilling machines the aim is to separate and draw out the fibres and lay them parallel; here the predominating object is drawing only. The pressure on the fibres is therefore smooth and elastic, encourag-

ing them to slip over one another and fall into line in the very gentlest manner possible.

To preserve the coherence of the slivers and bring them to uniform quality, four, six, or eight slivers are combined on the first drawing frame. The sliver cans are ranged behind the back draw-

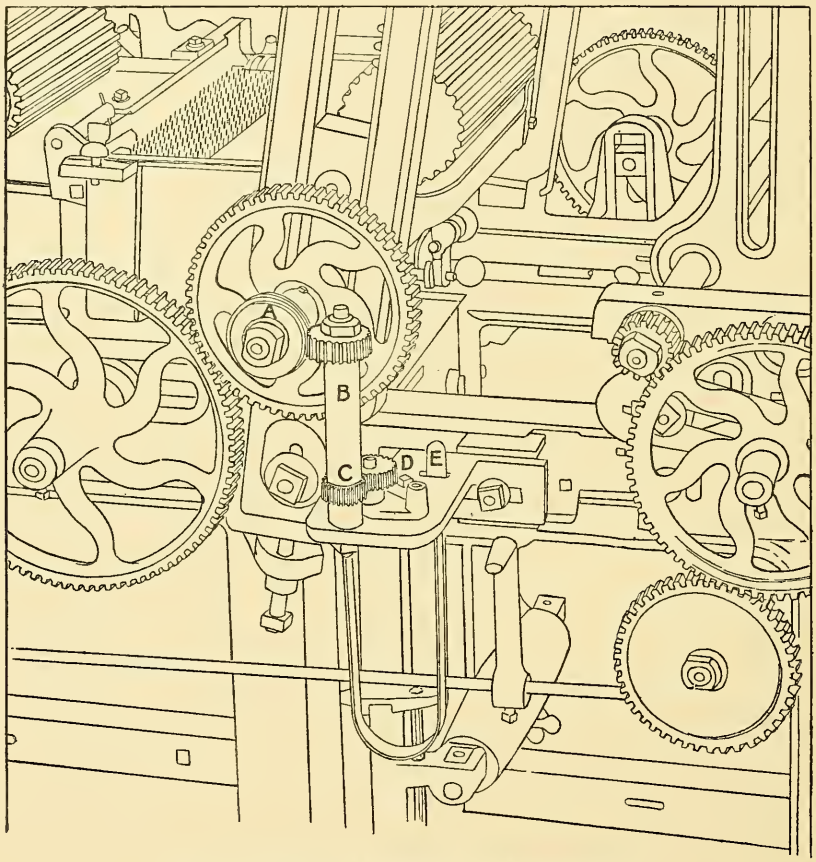


Fig. 107.—Spindle Gilling Frame, showing Knocker-off Motion

A, Worm on end of front roller; B, Shaft of measuring pinion; C, D, Wheels carrying knocker-off pinions; E, End of knocker-off lever

ing rollers and the slivers are guided into the grip of the back rollers, which compress them into unity and send them forward to the first of the faller gills which comes bobbing up. Borne on the upper pair of screws, the gills draw the wool out and onward to the front rollers, dropping down on to the lower pairs of screws at the end of their journey, having accomplished their mission. Revolving three, four, five, or six times quicker than the back rollers, the front

rollers pull out the slivers and deliver them over to the calender rollers, which press them into ribands and deliver into cans.

Some variations in practice must be allowed for, even on such a simple machine. It is usual to combine six slivers, but thick and heavy wools do better with four. Sometimes the operation on the first gilling and drawing frame is repeated; but the double gill box, with successive sets of gills and rollers, has come more into favour. The single frame undoubtedly produces the better work, but the double box is much quicker.

It is to be clearly understood that the work of the first gill box, as it is named, is purely drawing and doubling. A pure, clean, smooth sliver, with all the fibres lying evenly level, is all that we require from the operation.

Roller Drawing.—As a rule the reach on a drawing gill box is from 8 to 10 in. A shorter length would cause the long wools to nip between the front and back rollers, and no drawing could take place. But the fine Botany and other short worsted wools have to be considered. Coming close after each other, the gills carry the short fibres over the reach cleanly enough; but when the gill falls, it is apt to leave a ragged end on the slivers composed of short fibres. To meet this difficulty the obvious resort is a pair, or two pairs, of drawing rollers in place of the faller gills. In effect the worsted roller drawing machine is the same as the cotton drawing frame. Very often, indeed, the wool has come through the same process as cotton. It has been carded only. Here, as in many other instances, the two processes approximate.

Larger in every part, with wider spaces between the pairs of drawing rollers, the worsted-drawing frames are worked on the same principles as the cotton-drawing frames. It is a curious fact, however, that the roller drawing frames employed by the worsted men are always a stage behind the cotton frames in development. Whether this arises from a comparative lack of enterprise or a less strenuous competition we cannot undertake to decide.

French Drawing Frames.—The first stage in the French system of drawing is carried through on the gilling frame already described; but the second stage is also a drawing operation pure and simple. Hence it falls to be considered in this section.

The inventors of the French drawing frame (fig. 108) have sought to make it the epitome of all textile preparing machines. First, there are the back rollers, the lower one corrugated and the upper one plain.

Next we find what is called the porcupine roller, which is a kind of cylindrical adaptation of the faller gills. It is a cylinder closely studded with fine, needlelike points, and set so that its periphery is higher than the nip, or point of contact, between the back rollers. The

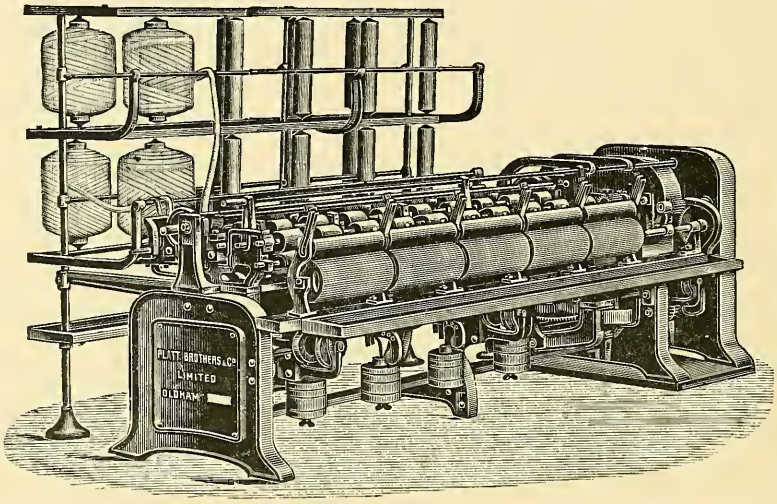


Fig. 108.—French Drawing Frame

height of the porcupine roller has two advantages; it grips on to the wool more closely than if the periphery were level with the nip, and offers to the wool a wider drawing surface. The sliver is drawn round the porcupine roller, but the pins are so disposed that they

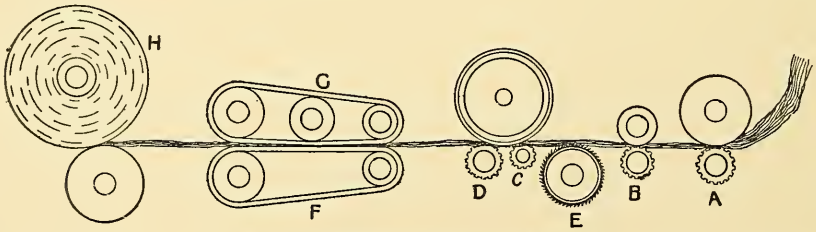


Fig. 109.—Diagram of French Drawing Frame

A, B, C, D, Fluted rollers; E, Porcupine; F, G, Leather bands having a slight transverse movement; H, Balling head

do not hook into the fibres and let the front drawing rollers, which are revolving in close proximity, take ready possession. Between these parts of the frame the draft of the sliver is determined. The porcupine roller has a greater surface speed than the back rollers, and the front rollers have a higher speed than the former. The

relative speeds are arranged according to the length of draft desired. But we have not come to the end of the frame. Before the front rollers are pairs of rubbing or condensing leathers, such as are employed on the woollen condenser. Endless sheets of leather are stretched over two pairs of rollers, the rollers having a transverse as well as a revolving motion. Passing between these rubbing leathers the slivers are condensed and rolled into close consistency without twist. From these rubbers the slivers are taken by bobbins which oscillate to and fro, winding on the yarn in a spiral shape.

Points in Worsted Drawing.—Whatever drawing frame we use, the wide margin of difference in the lengths of the fibres in every kind of wool must always be kept in mind. In adjusting the rollers, faller gills, and other appliances, and in the grading of the drafts, the nature of the fibre has to be taken into account. The ends of the wool should show as little as possible, otherwise twitty threads will result. The main aim in worsted drawing, speaking generally, is to obtain an even sliver in which all the fibres lie parallel. For that purpose the first gill box employed in the English system is admittedly imperfect, and needs the elaborate treatment on the bobbin-and-fly frames following to supplement it. But good workmanship on this frame will greatly assist in the production of a fine thread.

Draft calculations are the same on all drawing frames, and the formulæ already given in this chapter may be applied to every kind of machine.

Flax Drawing.—Having been formed on the spreadboard, the flax slivers are weighed in the cans, which are all of equal weight and grouped in sets. A few words of explanation are needed to make this point clear. The flax slivers have been made equal in length, but the weights are unequal. Inequality in sliver weights can be minimized by the skill and care of the operatives. If anyone were to set out from the very beginning of the manufacturing process with the determination to prove that fine flax could be made into slivers of equal weight on the spreadboard, it could be done; but the test would only serve to demonstrate the force of industrial and economic conditions. Handling a heavy fibre like flax, with the speed demanded by factory conditions, the workers cannot be expected to regulate accurately every ounce of weight. Therefore slivers supposed to be of the same count of roving, in practical work, range in weight from 7 yd. to 9 yd. per pound. In fine rovings the varia-

tion is less; on coarse flax the variations are frequently wider. But in every class it is necessary to obtain yarns of a uniform length to weight, and the basis of such yarns is laid by the drawing frame.

Flax-drawing Frames.—Being a long and strong fibre, flax is suitable for drawing on the gill frames, the faller gills allowing just the free movement the fibre demands, while sufficiently separating them. In structure the flax-drawing frame (fig. 110) has features peculiar to itself. The frames are generally made up of two or three sections

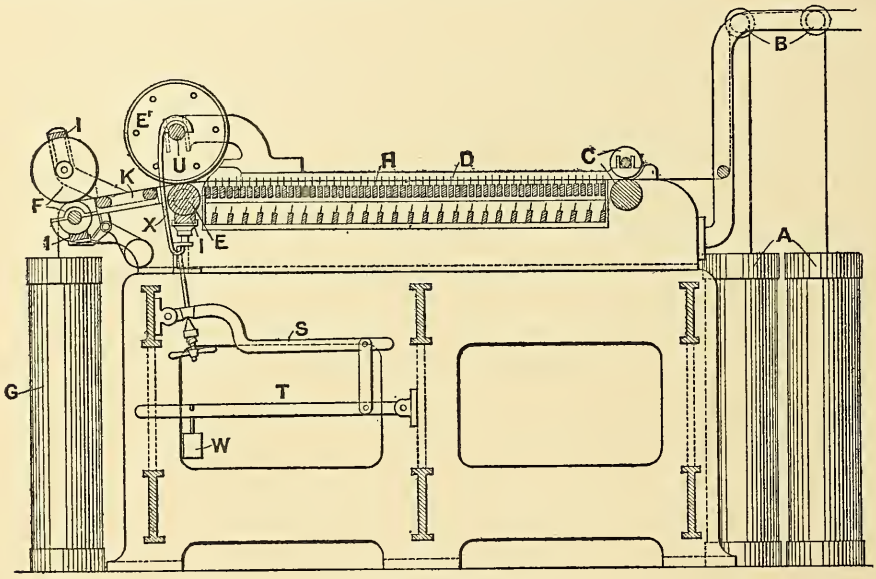
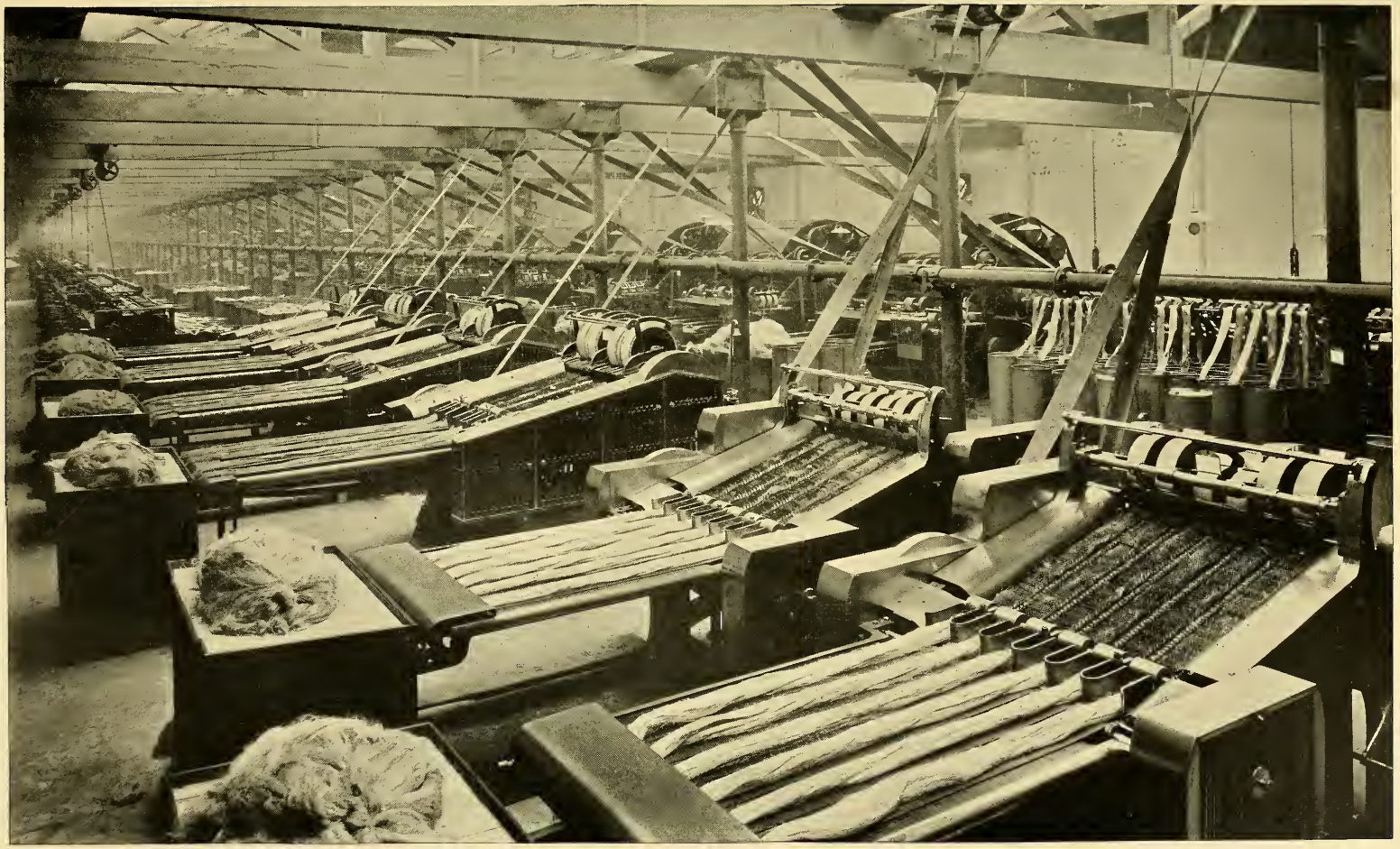


Fig. 110.—Flax-drawing Frame

A, Cans from spreadboard or preparing machine; B, Sliver guide pulleys; C, Feed rollers; D, Gill bars or fallers; E, Drawing rollers; F, Delivery rollers; G, Can for next drawing; H, Upper slides; K, Doubling plate. Pressure is applied to the axle U of the upper drawing roller by means of the weight W, and transmitted by the hanger X and the levers S and T.

containing four, six, or eight heads, according to the system of the factory. A set of heads is a complete machine, the linking of two or three together being for driving purposes mainly. Again, each head might be considered independent if the requirements of doubling could be left out of the account. At the back of the frame the conductor pulleys sit on rails the length of the range of heads; the pairs of back rollers similarly correspond; the gill bars carry the same number of combs; the front rollers are, of course, the heads, and number four, six, or eight, according to the size of the frame. In other words a drawing machine consists of a pair of sliver pulleys, a pair of back rollers, one gill comb on each bar, and one



PREPARING AND DRAWING FLAX SLIVERS, BLOOMFIELD MILL, BELFAST

(Belfast Ropework Company, Ltd.)

pair of drawing rollers. Every sliver, or pair of doubled slivers, passes through the frame independently and distinct from every other. The combination in delivery is afterwards done in accordance with the scheme of draft.

General Principles of Doubling and Drawing Flax.—One of the principal functions of flax drawing is to make a sliver of known weight to length; in fact, the whole of the material must be brought to uniformity before it leaves the drawing. The first drawing frame is named the *set drawing frame.* A set is the number of slivers which are drawn and combined into one on the frame. Into each head a pair of slivers are fed; therefore the set for a frame of six heads is 12, and for a frame of eight heads the set is 16 slivers. It is the duty of the drawing master to combine slivers of such weights that together they will produce the sliver of desired weight to length. Say, for example, the weight of the spreadboard sliver is to be 8 yd. to the pound, the whole of the 12 or 16 slivers must give an average of 8 yd. We might take three of 9 yd., four of 7½ yd., and five of 8 yd. to the pound to make up a set of 12, producing an average of 8 yd. This is a very simple case, and is to be understood as an illustration only. The number of the spreadboard from which they have been derived and the weights of the slivers are marked; selection is therefore merely a matter of arithmetic, and is generally entrusted to a lad, after the weight of the drawing has been chosen.

With a draft of six to one the sliver comes from the first drawing frame heavier than any one of those put in; but a greater mass of fibres is contained within it, lying closer and more evenly together. Most important of all, in place of many slivers of varying weights one sliver of ascertained weight to length has been produced.

Faults in Flax Drawing.—Not many years ago the drawing of flax was very largely dependent on the skill and conscientiousness of workers not highly paid. We have purposely described the bare drawing frame, because that was the machine on which the industry formerly depended, and in the operation of which many of the spinners of the present generation were trained. It is evident that on such a frame "single", or the falling away of one sliver, was bound to occur. A sliver might pass through the back rollers and from one cause or another go no farther, while the companion sliver passed on. The gills might fail to catch it, or the fluting of the bottom roller be clogged. If the operator detected the absence of motion of the sliver over the pulley, no more than the sliver which had "singled"

was wasted; but the constant movement of the rollers might overcome the obstruction and again set the sliver in motion before the fault was observed, and the single would go through unnoticed, to affect the whole production, causing a softness and lightness in the yarn otherwise inexplicable.

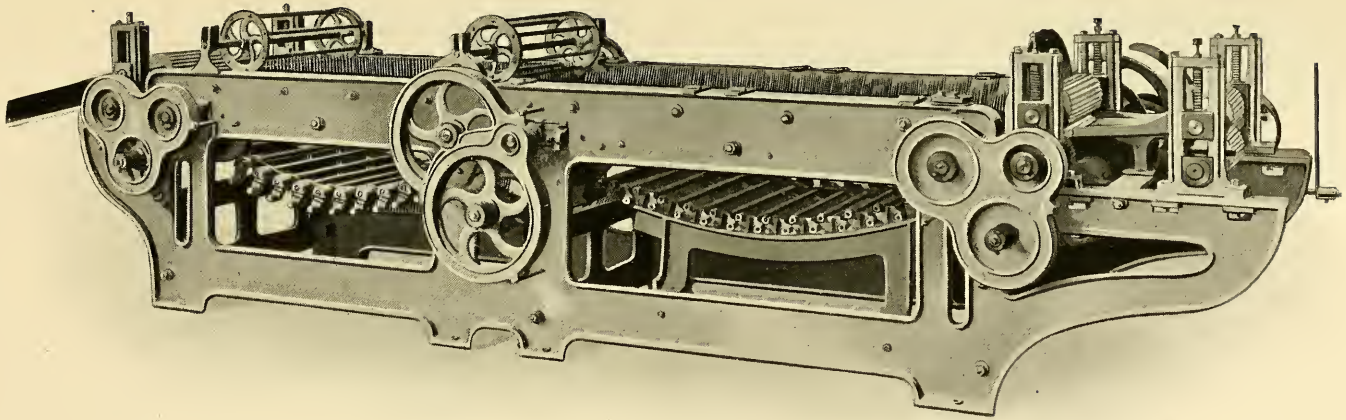
Licking on the rollers was another fault in flax drawing which only the skill of the operative was relied upon to avert. A few fibres frayed out and ran over the top roller of the back pair, and if not checked at once the fault became serious, the whole sliver being dragged over. The only way of curing that defect in those days was to stop the frame.

Another fault was the gathering of waste behind the rollers; the knot frequently passed through with the sliver, the sudden thickness breaking the gill pins.

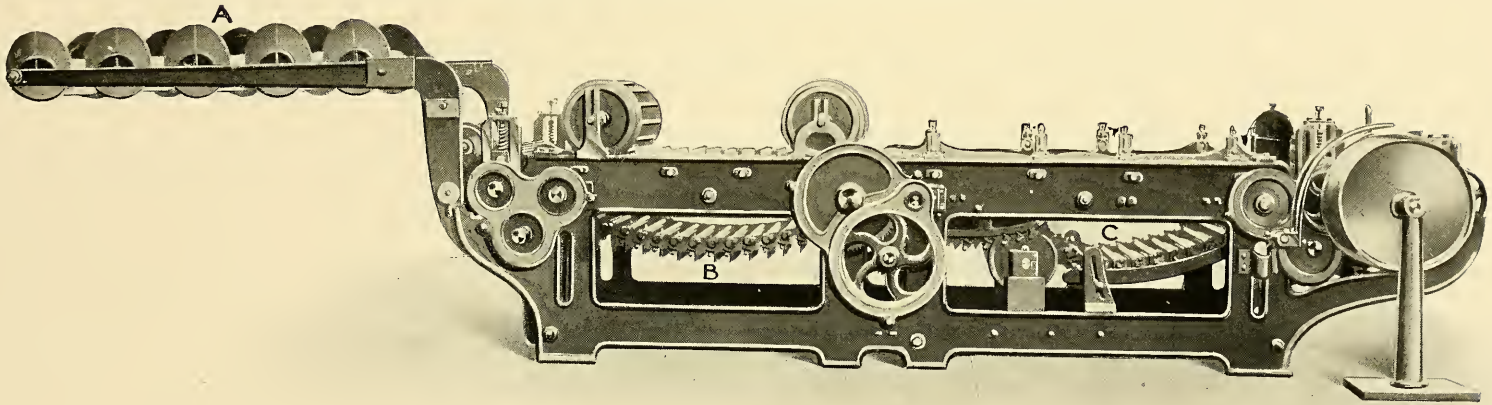
Upon the new frames none of those faults are allowed to pass. Every doubled sliver is gathered into the mouth of a trumpet in the throat of which is a detector, like a diaphragm, set exactly to the thickness of the sliver. If the sliver singles or thickens from any cause the diaphragm acts on the drive and stops the frame. At the other side, before the front roller, another diaphragm is placed. Both act in the same way as the spoon lever on the cotton frames. Those improved appliances have been of great service to the linen trade, adding largely to the quality of the rovings and lowering the cost of production.

Continued Drawing.—Three times the slivers are drawn on machines of similar structure, with finer gills, the doubling method being maintained throughout. When a fine roving is desired, a fourth drawing frame is employed. Some firms used to try to obtain the same result by passing the sliver twice through the third frame, but the effect was not satisfactory. Working with a fibre of the highest textile quality, linen spinners were too apt in former days to rely upon the last stages of the process to rectify any slight defects in the preparatory operations; but experience showed them the error of that practice. Linen factories can now challenge comparison with those of cotton or wool for fineness of equipment.

Tow Slivers.—Being short in fibre, tow slivers are not treated in the same way as "line". When taken from the carding engine the slivers are nearly equal in weight and need not be doubled save for the purpose of mixing and bringing them to uniform quality. Fine tow is drawn on frames which are practically the same as cotton-



DOUBLE CHAIN GILL DRAWING FRAME FOR HEMP (Lawson & Sons)



DOUBLE CHAIN INTERMEDIATE DRAWING FRAME FOR FLAX (T. Larmuth & Co.)

A, Feed Yarn Guides. B, 1st Chain Gill. C, 2nd Chain Gill.

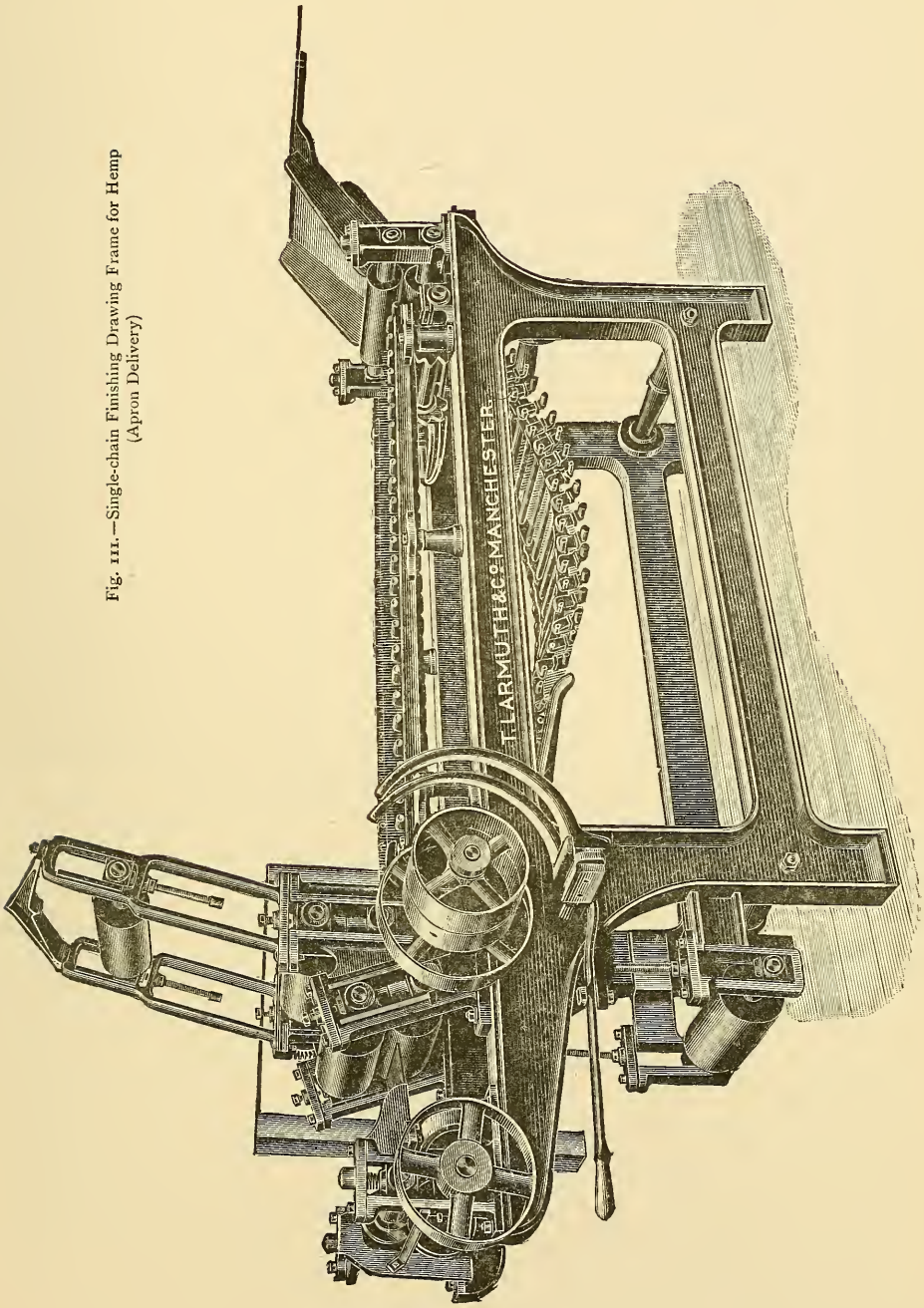


Fig. 111.—Single-chain Finishing Drawing Frame for Hemp (Apron Delivery)

drawing frames. When well selected no finer material comes into the hands of the linen spinner than these tows. Rovings of the highest spinning quality are thus drawn.

Lower qualities of tows, however, are drawn on the gilling machines, with precautions against twitty ends. For it must be perceived that a sliver composed of short fibres, if drawn on a reach too great for it, will show a great many fibre ends. This danger may be obviated by constant doubling.

Drawing Twine and Rope Slivers.—The ordinary hemp-drawing frames are simply large gilling machines. The slivers are taken from the spreadboard or carding engine and classified according to weight. Like the finer flax the hemp is grouped in sets, each set calculated to produce a given weight of sliver when all the slivers composing it have been combined in one. Through the drawing frame of four heads the eight slivers grouped are passed and combined on the calendering rollers into a single sliver. This sliver is generally calculated to equal in length the length of all the slivers which have been used to constitute it. That is to say, the draft is 8—1. It is of the same thickness as before, but finer, more compact, and of known weight to length. The second and last drawing frame for such slivers reduces them, the draft being from 8—1 up to 12—1 on the single sliver.

Another form of hemp-drawing frame, however, has come back into use, after being discarded for some time. This is known as the sheet gill drawing frame. Instead of being fixed on bars and carried along on horizontal screws, upper and lower, the gills are set in endless sheet chains, revolving on rollers. The one roller is hung before the back rollers of the drawing apparatus, and the other is next to the front drawing rollers. Sitting in rows on the endless sheet, the gill combs are carried across the reach in the same way as the combs of the faller gills; but instead of dropping down on to a pair of screw shafts, the gill combs simply turn round the rollers and pass to the other side under the frame. Being inclined slightly towards the back of the frame, the gills act in a gentle manner both when taking on the slivers and when giving them over to the front rollers. For rapid production the sheet gills are certainly better than the faller gills, but the latter still hold the field for fine work.

New Zealand Flax.—This material was originally imported from New Zealand as a competitor with flax for textile purposes. The

fibre is flax in structure, but lacks fineness and flexibility. British spinners have been disappointed in New Zealand flax, expecting too much, and now practise the other extreme of expecting too little. Up till lately jute-drawing frames have been commonly employed by users in this country, but in the native land of the fibre finer frames are used. If the fibre has been sufficiently well prepared, the hemp sheet gilling frame draws the flax very finely, and good rope rovings are obtained.

Flax and Hemp Preparing in General.—As we have hinted, the preparatory stages of flax and hemp drawing are being rapidly improved. In former years not enough attention was paid to those fibres, with serious consequences to the trade. Being old and established, the routine which had been observed from time immemorial was continued, in face of the competition of cotton, with the most perfect appliances which could be devised. Shortness of process has been found to be less economical than rapid and more elaborate processes, and the quality of the product has gained.

Jute Drawing.—The idea of reducing jute to the sliver condition by means of the carding engine was a bold one, but the venture has been justified by results. A carded sliver is always continuous and approximately uniform. Whatever inequalities there may be are inherent in the fibre itself. So far as mechanical contrivance can secure it, the equality of all carded slivers produced on the same kind and class of machine from the same kind and class of fibre is certain. For that reason jute drawing is the simplest of all drawing operations. To preserve the coherence of the sliver and bring the whole material to uniform quality the jute drawer doubles the slivers both in feeding and delivering; but the operation is general, and involves no selection of slivers nor minute calculations of weight to length.

The Jute-drawing Frames.—Built to draw a large and heavy fibre, the jute-drawing frames are of great size and weight. A complete carriage (fig. 112), as it is called, is composed of guide plate, retaining rollers, two pairs of screws, upper and lower, for carrying the gill bars, travelling bars 3 ft. long bearing each four gill combs 6 in. wide at the pins, drawing rollers, and delivery rollers. A frame may be made up of two, three, or four of these carriages.

Even after passing through the carding engine the jute fibres average about 10 in. long. To accommodate this great length special arrangements are provided. The guide plate is wide and

burnished, but the retaining rollers claim most attention. On the ordinary drawing frame the back rollers are paired, but here are three rollers, one large and two small. The first roller is small and acts as a feeder, drawing in the sliver from the guide plate; the second roller is large and the sliver is borne over it; the third roller is of the same dimensions as the first, the sliver passing in between it and the large roller, round under it, and into the sphere of the travelling gills. By this triple arrangement the whole length of the fibres is slowly fed into the drawing frame—hence the name, retaining rollers.

Compared with the size of the gill bars, the pitch of the upper

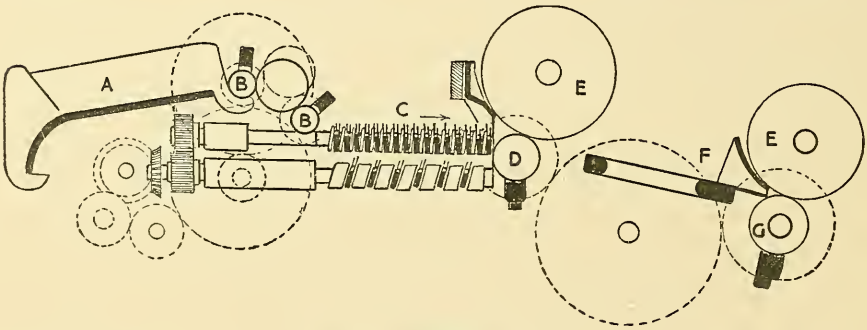


Fig. 112.—Jute-drawing Frame

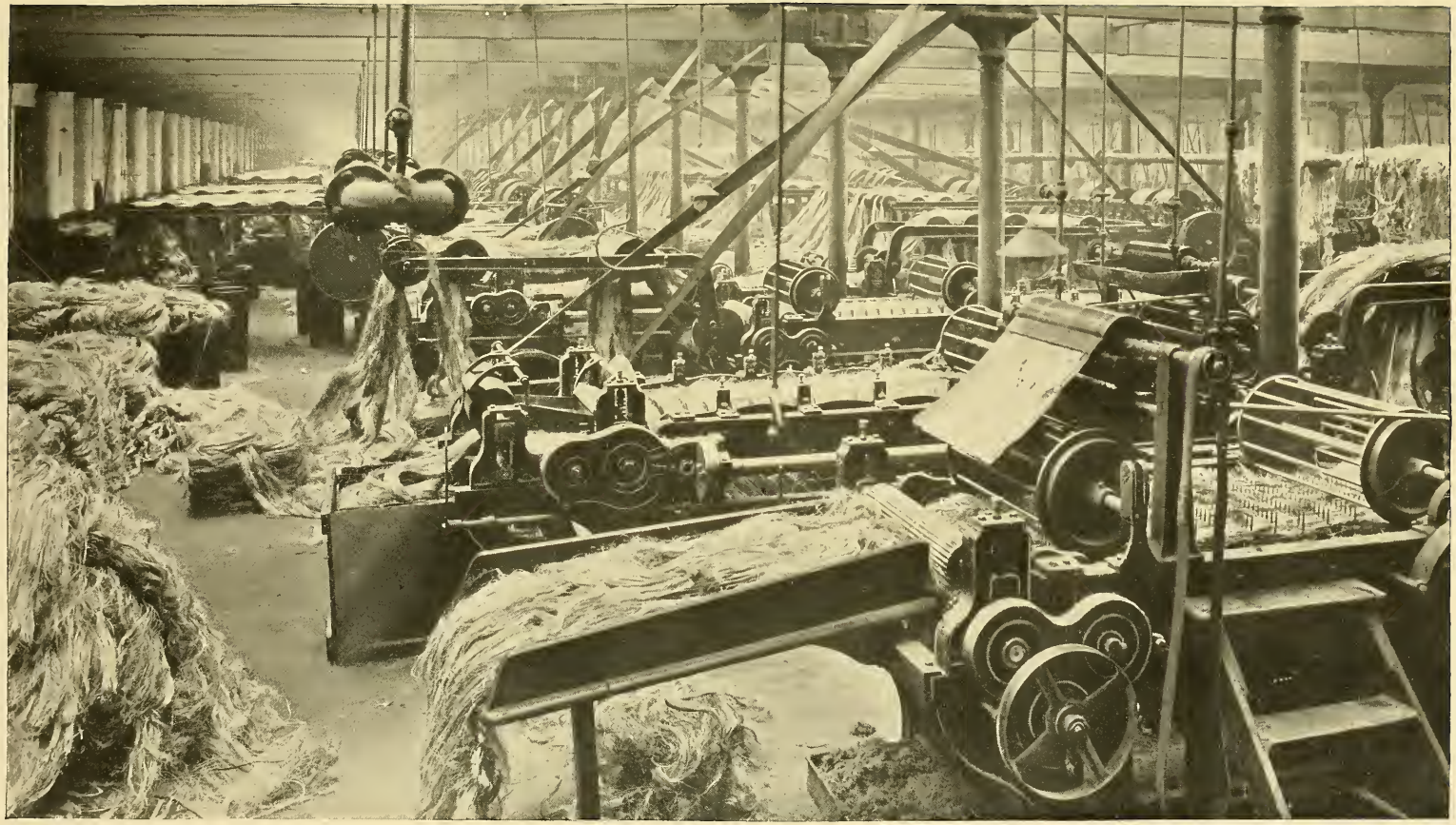
A, Guide plate; B, B, Retaining rollers; C, Gill bars; D, Drawing roller; E, E, Leather-covered pressing rollers; F, Delivery guide plate; G, Delivery roller

screws is very close, giving the gills a firm grip on the slivers, enabling them to draw steadily at the fibres. On the other hand, the pitch of the lower pair of screws is wide, economizing the gill bars, always keeping up the supply on the upper screws where the drawing is done.

The front drawing rollers are also specially large and heavy. The under roller is $2\frac{1}{2}$ in. in diameter and of cast steel; the upper and pressing roller is made of cast iron, covered with leather, and about 8 in. in diameter.

As the sliver comes through the drawing rollers it is usually joined to its neighbour on a doubling plate, and together they pass through the delivery rollers into the sliver can placed below.

Working the Jute-drawing Frame.—Taking as an example a frame of two carriages, we observe the method of working. There are four gills on each carriage, and the sliver is fed doubled; therefore sixteen sliver cans are brought from the finisher card and placed at the back



PREPARING MANILA ROPE YARN, POTTINGER MILL, BELFAST

(Belfast Ropework Company, Ltd.)

of the frame. Leading the slivers in pairs over the guide plate we allow the first of the retaining rollers to draw them, and by squeezing them between itself and the middle roller presses them into unity. In this condition the slivers pass over the top of the middle roller and round under the third roller. From the latter the sliver, now pressed into unity, is taken hold of by the gill, then being lifted up on to the upper pair of screws, the pins inserting themselves into the compact rope of fibres. Moving along the screw more quickly than the rollers deliver the sliver, the gill draws it out, a continuous succession of gills following to the same purpose. At the end of the screws the gills drop down, but at that point the end of the sliver is nipped between the front drawing rollers, with a surface speed six times faster than the retaining rollers, drawing the fibres still farther and elongating the sliver. As the sliver emerges from between the drawing rollers it is given a slanting direction, and doubled with the one next to it on the frame under the delivering rollers, which press them and send them out into the sliver can.

The Drawing Plan.—As may be understood, the carder may form slivers of any weight to length required; but the average sliver is about 8 yd. to the pound. Doubling in the feed we make a thick sliver of 4 yd. to the pound. Drawing six times the length we make 24 yd. to the pound. Doubling in delivery we produce a sliver from the first drawing frame of 12 yd. to the pound. Fine qualities of jute form into slivers on the carding engine, giving 10 yd. to the pound or more; but the plan of drawing is the same for any weight of sliver.

Second Jute Drawing.—The jute sliver is usually drawn twice. The second drawing frame is much finer than the first and the gills are closely set together or fitted in an endless revolving chain (fig. 113). Doubled at the feed the slivers are delivered singly into the cans.

Improvements in Jute Drawing.—The system of drawing and drawing frames described are those which perform the bulk of the work in the jute industry; but other and improved methods and machines have been devised which, though not yet considered commercially necessary, have demonstrated that jute may be put to higher uses than those in which it is at present employed. Adapting the English system of worsted drawing, one manufacturer has produced slivers of remarkable fineness and quality. Others have experimented in similar ways and obtained good results. These experiments may not be acted upon in the factory for years to come, and therefore it

is impossible to predict what shape they will take in practice. The facts are noted here, because, while our business is to give account of practical processes, we would guard against the supposition that any industry has become stereotyped in the form in which we have found it.

Ramie Drawing.—Like all newcomers, ramie is difficult to place. Though a commercial success, the manufacture of the fibre has not settled on definite lines. The most suitable machine for ramie is

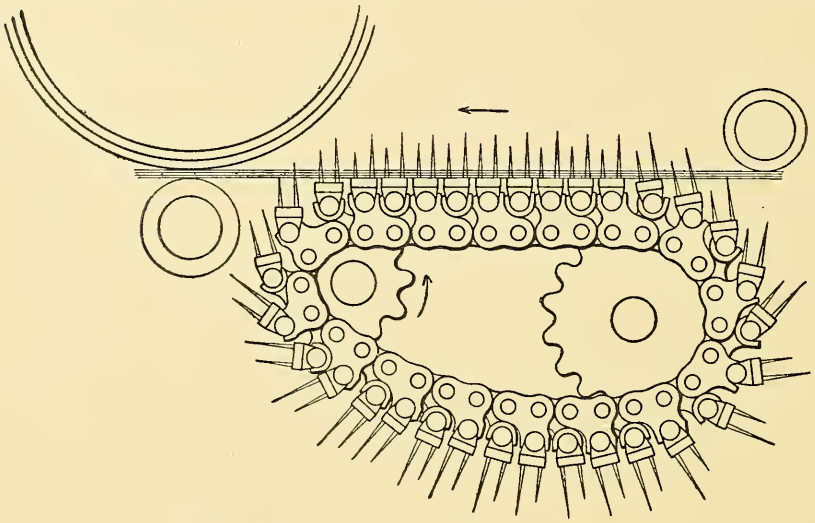


Fig. 113.—Jute-drawing Frame (S. Lawson & Sons, Leeds)

the French worsted-drawing frame, and the specialists in ramie machinery have taken up that line. As we pointed out, the ramie sliver is one of the finest in all textiles. Smooth, clean, regular, the filaments of nearly equal lengths and laid parallel, the sliver ought, one would think, to delight the heart of the drawer; but it does not. When drawn, the fine smoothness of the sliver is displaced by a twitty appearance, or rather a peculiar cloudiness, which can hardly be ignored. The elastic nature of ramie asserts itself. At this stage, however, it is unnecessary to deal with the drawing of ramie at length, the whole subject coming up in the next section.

Spun Silk.—From the combing machines three or four drafts are obtained, the longer of which are formed into slivers on the worsted gilling frames for that system of drawing, while the short draft is put through the carding engine, and the sliver drawn on the cotton system. The latter method is best studied on the cotton-

drawing frames. For the more important section of the spun silk the French worsted-drawing frame is almost exclusively employed. No better instrument could have been devised for treating soft silk than this worsted frame, and it was a fortunate circumstance that Lister, the first to utilize wild silks to any extent, was a worsted manufacturer. He had been familiar with the very machines required. Being a very good fibre, broken silk, once it has become a regular staple, or top, might be spun on any system; but the French worsted-drawing frame contained the secret of its most economical and successful manufacture.

When brought to the drawing frame the silk is a flat riband of soft fibres wound on a long spool in spiral shape. Hung on the back of the drawing frame, so as to be unwound with the least possible friction, the sliver is passed through the back rollers and on to the porcupines, which carry it forward to the front rollers. Drawn finely by the front pair of rollers, the refined sliver is rubbed and rounded in between the oscillating and revolving leathers and wound again on to large bobbins.

PARTICULARS OF DRAWING FRAMES

Cotton Frame

Heads in frame	1 to 4.
Deliveries per head	2 to 8.
Diameter of bottom rollers:	
Front roller	$1\frac{1}{8}$ in.
Second roller	$1\frac{1}{2}$,,
Third roller	$1\frac{1}{2}$,,
Fourth roller	$1\frac{1}{2}$,,
Diameter of top rollers:	
All the same	1 in.
Total draft of rollers	(Optional)
Distance between back and front rollers	,,
Weight on front top rollers	22 lb.
,, second ,, ...	17 ,,
,, third ,, ...	17 ,,
,, fourth ,, ...	17 ,,
Slivers doubled at each delivery ...	6 or 8
Height of can	36 in.
Inside diameter of can	9 ,,
Stop motions	tumbler or spoon lever.
Diameter of drum on main shaft ...	15 in.
,, pulleys on driving shaft ...	15 ,,
,, driving front roller ...	18 in. on shaft into 12 in. on front roller.
Revolutions main shaft per minute ...	285

Worsted Gill Boxes

Number of boxes...	2
Slivers fed...	6
Bottom rollers, front	2 in. tooth and pinion.
,, back	3 ,, ,, ,,
Top rollers front	$2\frac{1}{2}$ in. ,, ,,
,, back	$3\frac{1}{2}$,, ,, ,,
Number of fallers up	12
Screw pitch (upper)	$\frac{3}{8}$ in.
Length of reach	18 in.
Draft	5 in. (about).
Height of can	36 in.
Length of box	4 ft. 6 in.
Breadth ,, ...	4 ft. 2 in.

French Worsted-drawing Frame

Diameter of bottom back roller ...	$1\frac{1}{2}$ in.
,, second roller	$1\frac{1}{2}$,,
,, top back roller	$2\frac{1}{2}$,,
,, top second roller	$1\frac{1}{2}$,,
,, third bottom roller ...	$\frac{3}{4}$,,
,, fourth top roller	$1\frac{1}{2}$,,
,, third top roller	$4\frac{1}{2}$,,
,, porcupine	$2\frac{1}{2}$,,
Distance from back to front roller nip ...	10 ,,
Length of leather rubbers	$7\frac{1}{2}$,,
Revolutions per minute of rubbers ...	60
Oscillation of rubbers	1 in.
Draft	10 ,,

Flax-drawing Frame

Deliveries in each head	6 or 8
Number of heads in a frame	3
Diameter bottom back roller	2 in.
,, top ,, ...	4 ,,
,, bottom front roller	3 ,,
,, top ,, ...	6 ,,
Number of faller bars	8 on upper screw.
Number of faller gills on bars	4
Width of each gill comb	5 in.
Length of gill pins	6 ,,
Stretch of gilling...	10 ,,
Draft	8—1

Jute-drawing Frame

Number of heads in frame	3 or 4
Deliveries in each head	4
Diameter first back roller	$2\frac{1}{2}$ in.
,, second back roller	5 in.
,, third ,, ...	$2\frac{1}{2}$ in.
,, bottom ,, ...	$2\frac{1}{2}$,,
,, top ,, ...	8 ,,
Length of travelling bar	3 ft.
Pitch of screw	$1\frac{1}{2}$ to 2 in.
Number of gills on bar	4
Size of gill combs	6 in.
Draft	6
Stretch of draft	11 in.

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